

**Boulder City Council
STUDY SESSION**

**April 28, 2009
6 pm to 8 pm**

Floodplain Management

**1777 Broadway
Municipal Building
City Council Chambers**

Submit Written Comments to City Council
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TABLE OF CONTENTS

	Page
Introduction	3
Questions for City Council	3
Flood Management Work Program	4
I. Overview	4
II. Flood Mitigation Planning	4
III. Property Acquisition and Flood Mitigation Work Program	7
A. Current Policies and Guidance	8
a. Preservation of Floodplains	8
b. Flood Management	8
c. Non-Structural Approach	9
d. Protection of High Hazard Areas	12
e. Larger Flooding Events	15
f. Flood Hazard Land Use Analysis	15
B. Critical Facilities and Vulnerable Populations	16
C. Property Damage and Other Cost Issues	19
D. Collaboration with Greenways Program Objectives	22
IV. Next Steps	24

Attachments:

A – Map of Major Drainageways in Boulder

B – Map of Floodplains in Boulder

C – Fourmile Canyon Creek and Wonderland Creek, Council Agenda Item dated Nov. 10, 2008

D – Map of Residential Structures Located in the High Hazard Zone

E – Critical Facility Information

F – Map of Critical Facilities Located in the High Hazard/Conveyance Zones

Introduction

The purpose of this study session is to present information and discuss issues raised during the Nov. 10, 2008 public hearing regarding the Fourmile Canyon Creek and Wonderland Creek Flood Mitigation Plan. At that public hearing, concerns were raised regarding:

1. the intent and interpretation of current city flood policies,
2. vulnerable populations to flooding, especially Crestview Elementary School,
3. the cost of the proposed property acquisition and flood mitigation plan, and
4. the priority of the proposed work compared to other flood hazard areas in Boulder

This document provides City Council with information regarding these issues in preparation for the April 28, 2009 study session discussion. Specific issues and analysis related to the city's property acquisition and flood mitigation program are presented to provide additional information for council in considering whether to approve, at a future city council meeting, the Fourmile Canyon Creek and Wonderland Creek flood mitigation plan.

Questions for City Council

Staff is suggesting the following questions to guide City Council's discussion at the study session:

1. Does council agree with staff's approach to flood mitigation planning and the role it plays in Capital Improvement Program (CIP) project prioritization?
2. Does council have questions about current flood policies how they are being applied in the proposed Fourmile Canyon Creek and Wonderland Creek Flood Mitigation Plan?
3. What feedback does council have regarding the development and analysis of preliminary, draft regulations pertaining to critical facilities and vulnerable populations located within the 100-year and 500-year floodplains?
4. What feedback does council have regarding the proposed Fourmile Canyon Creek and Wonderland Creek flood mitigation plan regarding costs, benefits and priorities?
5. Does council have questions regarding the proposed next steps for either the Fourmile Canyon Creek and Wonderland Creek flood mitigation plan or the draft regulations pertaining to critical facilities and vulnerable populations?

Flood Management Work Program

I. Overview

Boulder is located at the base of the foothills where there is high potential for flash flood events that allow little time for warning. Including Boulder Creek, there are 15 major drainageways that pass through the city of Boulder - see **Attachment A**, with the 100-year floodplains from these drainageways occupying 15 percent of the land area of the city of Boulder – see **Attachment B**. A major flood event could result in substantial loss of life and property damage. Because the threat to life and property damage is so great, the need to monitor, regulate and mitigate the impacts of flooding is critical.

The flood management program was most recently defined in the Comprehensive Flood and Stormwater Master Plan, which was accepted by City Council in 2004. Five guiding principles and work program elements were defined in the master plan as follows:

1. Preserve Floodplains (*floodplain mapping*)
2. Be Prepared for Floods (*flood education and insurance*)
3. Help People Protect Themselves from Flood Hazards (*flood preparedness*)
4. Prevent Adverse Impacts and Unwise Uses in the Floodplain (*floodplain regulations*)
5. Seek to Accommodate Floods, not Control Them (*property acquisition and flood mitigation*)

This study session packet format includes specific sections of a description and analysis of the topic (as shown in the Table of Contents), directly followed by a brief description of how the proposed Fourmile Canyon and Wonderland Creek mitigation plan responds to the topic, along with a re-statement of the respective “Questions for City Council.”

II. Flood Mitigation Planning

Each year in the United States, natural disasters take the lives of hundreds of people and injure thousands more. Floods are America’s #1 natural disaster and can happen anytime, anywhere. In fact, 90 percent of all natural disasters in the U.S. involve flooding. Nationwide, billions of dollars are spent annually to help communities, organizations, businesses and individuals recover from these disasters. This money only partially reflects the true cost of disasters because additional expenses to insurance companies and non-governmental organizations are not reimbursed by tax dollars. Many natural disasters are predictable, and much of the damage caused by these events can be alleviated or even eliminated through proper planning.

The city of Boulder first adopted floodplain regulations in 1969, in response to Front Range flooding events that demonstrated the flood potential and need for protective measures within the city. The city’s Stormwater and Flood Management Utility was established in 1974. The current floodplain regulations were adopted in 1989 and established three specific flood zones used to manage and regulate development and uses within the floodplain. These zones are the 100-year floodplain, conveyance zone and high hazard zone and are described as follows:

- **The 100-year Floodplain** is defined as all land areas subject to inundation by flood waters that have a one percent (1%) chance of occurring.
- **The Conveyance Zone** represents a corridor within the floodplain that should be preserved to pass the flood water, anticipating that debris will create blockages during a large storm event.
- **The High Hazard Zone** is an area of the floodplain where the combination of water depth and water velocity are expected to be too great for some people (e.g., young children and elderly) to maintain their balance should they be caught in a flash flood or attempt to cross a flood area.

Proactive mitigation planning helps reduce the cost of disaster response and recovery to the city and its property owners by protecting critical community facilities, reducing liability exposure, and minimizing overall community impacts and disruption. Boulder has been affected by natural hazards in the past and is committed to reducing future disaster impacts and maintaining eligibility for federal funding.

The city's Comprehensive Flood and Stormwater Master Plan outlines the overarching policy issues for the Stormwater and Flood Management Utility, while specific flood mitigation plans are developed for each drainageway.

Flood mitigation plans, such as the one for Fourmile Canyon and Wonderland creeks, provide a long-range plan that can be used to prioritize capital improvement projects in the context of the overall flood Capital Improvement Program (CIP) and are similar to subcommunity and area plans, which inform development standards and zoning in certain areas of the city. Mitigation plans are updated periodically to address new information related to flood mapping and modeling, as well as physical modifications in the drainageway, and they provide information that allows staff, private property owners and the development community to plan and coordinate activities in recognition of the flood hazards and potential mitigation strategies.

In most cases, the drainageway mitigation studies and plans are developed in cooperation with the Urban Drainage and Flood Control District (UDFCD). In doing so, the city is eligible to receive funding from the UDFCD to assist with the design, construction and maintenance of improvements to its major drainageways. The studies and plans are typically developed in two stages:

- Phase A – Alternatives Analysis, and
- Phase B – Prel. Design and Community and Environmental Assessment Process (CEAP).

Once the Phase B work has been accepted, projects are prioritized in the CIP to implement the plan within the budget constraints of the Stormwater and Flood Management Utility Fund. Priority is based primarily on the following factors:

1. Life safety (high hazard) mitigation
2. Flood emergency response capability
3. Critical facility (vulnerable population) hazard mitigation
4. Property damage mitigation
5. Collaboration with other Greenways Program Objectives

Last November, City Council considered accepting the proposed flood mitigation plan for Fourmile Canyon and Wonderland creeks. Acceptance of the plan does not obligate the city to fund any portion of the plan within any specific timeline since specific funding requests would be made through the annual budget process. One of the primary motivations for updating this particular plan was the significant changes in the city's understanding of flood hazards for the Fourmile Canyon and Wonderland creeks, based on the 2007 flood mapping changes. These changes rendered previous flood mitigation plans obsolete. Another motivation for updating the mitigation plan was the rapid development and redevelopment changes occurring within the North Boulder areas. The proposed flood mitigation plan would help guide future development and redevelopment activities in this area. The mitigation plan also allows the city to identify properties that might need to be acquired to reasonably mitigate life safety hazards associated with flooding.

The flood mitigation studies and plans also allow city staff to look for opportunities to leverage limited city funding with other funding sources, such as through the city's Greenways Program. For example, if the city's Transportation Division decides that a bridge or culvert needs to be replaced, then the flood mitigation plan provides information regarding the size of the bridge or culvert that is needed to pass the designated flood event. The upgrades to the bridge then are made in cooperation with the Transportation Division on a timeline that allows for the most efficient use of resources.

Funds are available through the Stormwater and Flood Management Utility Fund and, if the associated mitigation projects are deemed to be of high priority, the city may decide to actively pursue components of a flood mitigation plan. This is done through the annual budget process. Proposed projects and expenditures are reviewed by the Water Resources Advisory Board (WRAB), Planning Board and City Council. Because projects typically have a significant cost that exceeds annual revenue, it is likely that flood mitigation plans will require decades to fully accomplish. There is the potential that a major flood will occur before all of the mitigation improvements are implemented, which is why prioritization of projects within a plan and among all the city's mitigation plans is so important.

Boulder has its share of success stories. Even when a flood mitigation plan is not fully implemented, whenever any mitigation project is completed, the community benefits from the results. Previously constructed improvements have already provided significant benefits to Boulder. For example, a significant storm event on Aug. 15, 2007 along Bear Canyon Creek would have likely flooded a day care center located immediately adjacent to the creek if flood mitigation work had not been previously accomplished.



Bear Canyon Creek – August 15, 2007

The recent federal economic stimulus funding provides another incentive for the city to develop plans and designs so that projects may qualify for these funds by becoming “shovel ready” in the near future. Although none of the projects associated with the proposed Fourmile Canyon and Wonderland creeks plan are considered shovel ready for this round of stimulus funding, there may be additional stimulus funding or other federal funding programs through which projects could be qualified.

City Council adopted the multi-hazard mitigation plan (MHMP) in August 2008 in order to make the city and its residents less vulnerable to future natural hazard events. The plan was prepared pursuant to the requirements of the Disaster Mitigation Act of 2000 in order for the city to be eligible for the Federal Emergency Management Agency’s (FEMA) Pre-Disaster Mitigation and Hazard Mitigation grant programs. It is anticipated that projects identified in the Fourmile Canyon and Wonderland creeks plan would be eligible for these pre-disaster mitigation grants.

Fourmile Canyon and Wonderland Creeks

The Fourmile Canyon and Wonderland creeks flood mitigation plan, including the Phase A report developed by Love & Associates, analyzed various alternatives designed to mitigate flood hazards along these creeks. The work was jointly sponsored by the Urban Drainage and Flood Control District and the city. This plan was presented to City Council on Nov. 10, 2008 during a public hearing and a copy of the agenda item and selected attachments is presented as **Attachment C**.

Staff considered the cost and priority of the proposed work compared to other flood hazards in the city and based on five prioritization factors mentioned above on page 5. The public process included two open houses and several public hearings with the Water Resources Advisory Board (WRAB) and Planning Board. Based on the feedback received during this process, several flood mitigation alternatives were evaluated and refined. Staff considered this feedback in formulating the recommendations made to City Council in November 2008.

<p><i>Question #1: Does council agree with staff’s approach to flood mitigation planning and the role it plays in CIP project prioritization?</i></p>
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III. Property Acquisition and Flood Mitigation Work Program

During the Nov. 10, 2008 public hearing regarding the Fourmile Canyon Creek and Wonderland Creek flood mitigation plan, concerns were raised regarding:

1. the intent and interpretation of the non-structural approach policy,
2. vulnerable populations to flooding, especially Crestview Elementary School,
3. the cost of the proposed property acquisition and flood mitigation plan, and
4. the priority of the proposed work compared to other flood hazard areas in Boulder

Specific policies and analysis related to the city's property acquisition and flood mitigation program are presented as follows:

A. Current Policies and Guidance

Flood related policies were last reviewed as part of the 2005 major update to the Boulder Valley Comprehensive Plan (BVCP). The current plan lists several policies related to flood management as follows:

a. BVCP Policy 4.20 – Preservation of Floodplains

“Undeveloped floodplains will be preserved or restored where possible through public land acquisition of high hazard properties, private land dedication and multiple program coordination. Comprehensive planning and management of floodplain lands will promote the preservation of natural and beneficial functions of floodplains whenever possible.”

This policy is being implemented in part through the city's Greenways Program that encompasses and integrates the protection and restoration of habitat, enhancement of water quality, flood mitigation and drainage, alternative transportation routes for pedestrians and bicyclists, recreation and protection of cultural resources. The city's floodplain and wetland regulations that work to preserve the natural and beneficial function of floodplains and associated riparian areas also serve to implement this policy as well as on-going review of annexation and development proposals. However, when public land acquisition is not economically feasible or possible, current city floodplain regulations do not prevent redevelopment of these properties but require suitable flood protection measures and allow structural mitigation of high hazard and conveyance zone impacts.

Fourmile Canyon and Wonderland Creeks

The recent update of the floodplain mapping for Fourmile Canyon and Wonderland Creek as well as the guidance provided in the proposed flood mitigation plan promotes the effective implementation of this policy. For example, previously unknown flood hazard areas are now being addressed through the city's floodplain regulations that limit development in flood prone areas. The dedication of private land along Fourmile Canyon or Wonderland Creek to preserve the natural and beneficial function of the floodplain is a normal condition for county parcels whose property owners wish to annex to the city.

b. BVCP Policy 4.21 – Flood Management

“The city will protect the public and property from the devastating impacts of flooding in a timely and cost-effective manner while balancing community interests with public safety needs. The city will manage the potential for floods by implementing the following guiding principles:

a) Preserve floodplains

b) Be prepared for floods

c) Help people protect themselves from flood hazards

d) Prevent unwise uses and adverse impacts in the floodplain

e) Seek to accommodate floods, not control them”

This policy was adopted in consideration of the Comprehensive Flood and Stormwater Master Plan guiding principles and work program elements that form the basis for the city's flood management and mitigation program.

Fourmile Canyon and Wonderland Creeks

These policies have been considered as part of the proposed flood mitigation plan. Staff balanced community interests and modified the final recommendations for flood mitigation in several areas. For example, along Fourmile Canyon – Reach 4 initial recommendations called for containment of the 100-year flood event but because of aesthetic and cost concerns the recommendation were modified to contain the high hazard zone only.

c. BVCP Policy 4.22 – Non-Structural Approach

The city will seek to preserve the natural and beneficial functions of floodplains by emphasizing and balancing the use of non-structural measures with structural mitigation. Where drainageway improvements are proposed, a non-structural approach should be applied wherever possible to preserve the natural values of local waterways while balancing private property interests and associated cost to the city.

This policy was modified during the 2005 major revision to the BVCP to revise the previous policy statement. Between 1978 and 1995, the BVCP reflected a policy that required a “non-containment approach to flood management on Boulder Creek and a generally non-structural approach to flood control on all major water courses and drainageways.” This approach and policy originated in 1978 when the work of the city's Boulder Creek Subcommittee evaluated the U.S. Army Corps of Engineers' Committee on Environmental Planning report. The city's subcommittee submitted an 11-point plan concentrating on non-structural approaches to flood management. In 2005, the policy was revised to reflect a more consistent manner to floodplain management.

City staff is now implementing this policy for Boulder Creek and other major drainageways by interpreting the meaning of the non-structural approach in the following manner:

Non-structural: A non-structural approach is flexible in allowing modifications to the creeks and adjacent landscape that provide containment of flood waters. It emphasizes that such modifications have a natural appearance, avoiding the use of hardened structures, and provide water quality and wildlife habitat enhancements.

Because of the large volume of water associated with a Boulder Creek flood (100-year flood flow equals nearly 12,000 cubic feet per second at the mouth of the canyon), full or partial containment of the 100-year flood event would require either 1) a massive conveyance structure incompatible with Boulder's existing character or 2) significant land area requiring the removal of existing structures that currently support Boulder's economy. Since either of these approaches would be very costly, the current focus is on

the containment of the high hazard flood flows through selected property acquisition and excavation outside of the main Boulder Creek channel.

Excavation outside of the main channel of the creek is called “overbank” excavation. The most notable project along Boulder Creek occurred in 1993 and was accomplished in collaboration with the Boulder Valley School District. Nine properties were purchased in the vicinity of Boulder High School and 13th Street. The structures were removed and the overbank area on the north side of the creek, south of Arapahoe, was excavated and graded to provide for additional flood conveyance and the construction of park and athletic fields, as shown in the photo below.



Boulder Creek Overbank Excavation Mitigation West of Boulder High School

Other private structures along Boulder Creek that have been acquired and removed since 1989 include:

- City Tree House (Parks and Recreation) office structure on the south side of Boulder Creek, east of the Library
- Residence at 1234-18th St., along the north side of Boulder Creek
- 18-unit apartment complex at 299 Arapahoe Ave., just east of the Eben G. Fine Park, on the south side of Boulder Creek
- Residences at 1228 and 1230-17th St., along the north side of Boulder Creek

Other flood mitigation improvements that have been implemented along Boulder Creek since 1989 include:

- Lower Arapahoe Avenue Bridge structure replaced just east of Broadway
- 17th Street Bridge replaced with a 100-year structure
- Conveyance/detention storage improvements through CU’s Research Park
- Railroad underpass structure at Cottonwood Grove
- Upper Arapahoe Bridge structure replaced above Eben Fine Park
- 55th Street Bridge replaced with 100-year structure
- Replacement of the Broadway Bridge with 100-year structure
- Elimination of 29th St. shopping area from 100-year floodplain based on fill

Because the volume of water associated with floods on other major drainageways is not as significant as Boulder Creek (Fourmile Canyon Creek 100-year flood flow equals about 3,000 cubic feet per second at the mouth of the canyon), full or partial containment of 100-year flood flows is feasible using a combination of property acquisition, excavation and limited structural solutions. The acquisition of property allows for fewer structural approaches to be implemented.

The city has implemented many flood containment and mitigation projects along major drainageways, most notably Goose Creek and Bear Canyon Creek. These projects have used a combination of non-structural approaches that emphasize a natural appearance and some structural solutions where the expense of purchasing existing structures was deemed too great.

Bear Creek and Goose Creek are examples of this combined approach, as shown in the following photos:



Bear Canyon Creek flood mitigation improvements in Martin Park



Goose Creek flood mitigation west of 28th St.

Fourmile Canyon and Wonderland Creeks

It is staff's opinion that the proposed flood mitigation plan for Fourmile Canyon and Wonderland Creeks complies with the non-structural approach policy. In most cases, there would be limited excavation in or near existing low-flow channels. Exceptions would be in areas where 100-year flood containment is deemed desirable because of the extensive property damage that would otherwise occur during flood events.

In all situations, the use of concrete would be minimized and there would be extensive revegetation effort for any improvement project. There are also opportunities to improve habitat and water quality through the creation of wetland areas that do not exist today.

d. BVCP Policy 4.23 - Protection of High Hazard Areas

“The city will prevent redevelopment of significantly flood-damaged properties in high hazard areas. The city will prepare a plan for property acquisition of flood-damaged and undeveloped land in high hazard flood areas. Undeveloped high hazard flood areas will be retained in their natural state whenever possible. Compatible uses of riparian corridors, such as natural ecosystems, wildlife habitat and wetlands will be encouraged wherever appropriate. Trails or other open recreational facilities may be feasible in certain areas.”

Life safety is a significant concern along Boulder's major drainageways. Many structures have been built in the designated high hazard flood zone, the area that poses the greatest risk to life safety. Life safety (high hazard zone) mitigation is a primary issue in prioritizing flood mitigation capital improvement projects.

Because of the large number of structures in the high hazard zone, a rating system was developed in 1997 by staff and a consultant based on potential threats to the safety of building occupants as well as the potential for damage to structures during the 100-year flood. Criteria (listed from most important to least important) included the following:

1. Overall safety of individuals within flood water near the structure
2. Ability of occupants to climb above flood water within the structure
3. Structural stability during flooding
4. Impact of rapid velocity flows
5. Possibility that occupants living in below-grade units may be trapped
6. Ability of occupants to leave or enter the building during a flood
7. Use of the structure
8. Site specific hydraulic conditions

Because evacuation during a flood event will be more difficult for people living in residential structures (for instance during the middle of the night when people are sleeping), it is appropriate to place a higher priority on the mitigation of life safety hazards for these structures than on commercial or industrial structures.

Based on an analysis performed in 1997, there were a total of 279 structures located completely or partially in the high hazard zone. Of the 279 structures in the high hazard zone, 41 structures received the highest rating.

Since 1997, several projects and acquisitions have either physically removed structures from the high hazard flood zone or changed the flood waters so that the high hazard zone boundaries changed to no longer impact certain structures. Recent improvements along Bear Canyon Creek have eliminated all structures from the high hazard flood zone. Improvements along Goose Creek, through the Mapleton Mobile Home Park, eliminated all structures (mobile homes) that received the highest rating based on potential threat. These same improvements also removed the two structures associated with Elmer's Twomile Creek. The city acquired and removed all residential structures that received the highest rating along Boulder Creek. The number of structures along Fourmile Canyon Creek has been reduced because of the 2007 flood mapping study update, but two structures were added along Wonderland Creek for this same reason. A structure along Twomile Canyon Creek has been added and it is unknown why this structure was not included in the analysis performed in 1997.

As of 2009, the total number of structures located in or partially in the high hazard zone has been reduced from 279 (in 1979) to 178 structures. Of the 178 total structures, 132 of them are residential structures that are completely or partially in the high hazard zone. Based on this information, 17 residential structures are associated with Fourmile Canyon and Wonderland creeks. Please refer to **Attachment D** for a map of the general location of residential structures in the high hazard zone.

Total number of residential structures in high hazard zone (2009)

<u>Major Drainageway</u>	
Boulder Creek/Boulder Slough	2
Fourmile Canyon	7
Wonderland	10
Twomile Canyon	21
Goose	37
Elmer's Two-mile	0
Sunshine Canyon	4
Gregory Canyon	29
South Boulder/Dry Creek No. 2	3
Skunk	13
Bluebell/King's Gulch	5
Bear Canyon	1
Viele Channel	0
Total	132

The following information presents the most vulnerable structures based on potential threat. Gregory Canyon Creek has the highest number of most vulnerable structures.

Most vulnerable residential structures in high hazard zone

<u>Major Drainageway</u>	<u>1997</u>	<u>2009</u>
Boulder Creek/Boulder Slough	5	0
Fourmile Canyon	5	2
Wonderland	0	2
Twomile Canyon	0	1
Goose	22	0
Elmer's Two-mile	2	0
Sunshine Canyon	0	0
Gregory Canyon	7	7
South Boulder /Dry Creek No. 2	0	0
Skunk	0	0
Bluebell/King's Gulch	0	0
Bear Canyon	0	0
Viele Channel	0	0
Total	41	12

Note: the increase in most vulnerable residential structures for Wonderland Creek in 2009 is due to recognition of the spill flow from Fourmile Canyon subsequent to 1997.

The anticipated capability of emergency management personnel to warn residents prior to a flash flood event is a significant consideration in determining the appropriate extent and priority of flood mitigation capital improvement project work.

Boulder and South Boulder creeks are by far the largest drainageways that flow through the city of Boulder. For these drainageways, the Urban Drainage and Flood Control District (UDFCD) early flood detection system called ALERT is available to provide real-time information that would aid in providing advance warning to residents of flash floods. This system is comprised of numerous rainfall and stream level gauges that provide data to assess flash flood potential in the foothills and canyons west of Boulder and is expected to provide up to 20-40 minutes of lead time prior to a flash flood event on these two creeks. (Longer warning times may be available under other types of flood events that develop more slowly due to extended periods of lower intensity rainfall.)

These gauges are not installed on the other drainageways as this type of system would not provide adequate notice of flash flooding along these drainageways, which are tributary to Boulder and South Boulder creeks. These tributary drainageways are relatively small and can develop runoff that produces flash flood affects in a very short period of time. It is unlikely that an early warning system could be designed for these drainageways that would provide adequate notice (20 minutes or more) to aid warning and evacuation efforts. In these cases, emergency response is likely to be confined to rescue efforts and sheltering in place methods

Another consideration is the ability of emergency response personnel to access and egress the flooded areas. The city has evaluated the affect of flooding on major roadways in Boulder and numerous roadways would be inundated during a major flood event.

For these reasons, the focus of high hazard (life safety) mitigation efforts on vulnerable residential structures along tributary drainageways that do not have an early warning system capability should be a higher priority.

Fourmile Canyon and Wonderland Creeks

From a high hazard (life safety) perspective, four of the city's 12 most vulnerable residential structures are located along Fourmile Canyon and Wonderland creeks. The proposed property acquisition and flood mitigation plan would mitigate the high hazard vulnerability of all these structures.

The proposed plan would also improve ability of emergency response personnel to access and egress the flooded areas along Fourmile Canyon and Wonderland creeks including those associated with Crestview Elementary School. This would be accomplished by containing the high hazard portion of the flood flows within a defined area and improving the conveyance of water underneath intersecting roadways including Upland Avenue and 19th Street.

e. BVCP Policy 4.24 – Larger Flooding Events

“Flood management has historically focused on and primarily addresses the impacts of a 100-year flood event. The city recognizes that larger flooding events will occur resulting in greater risks and flood damage that will affect even improvements constructed with standard flood protection measures. The city will seek to better understand the impact of larger flood events and consider necessary floodplain management strategies.”

The city currently maps the floodplain area associated with the 500-year flood event. The affect of this larger flood event is currently being assessed and considered for critical facilities as discussed below.

f. Flood Hazard Land Use Analysis (possible future policy)

Another flood management policy issue relates to the potential conflict between the BVCP community design and flood management policies and regulations. The primary concern is that a significant number of parcels with redevelopment potential have more than 50% of their land area in some portion of the floodplain. Several commercial and industrial parcels in particular have more than 50% of their land area in the high hazard zone or conveyance zones. The CFS Master Plan recommended a Flood Hazard Land Use Analysis which will assess the future development potential in the floodplain, explore various tools to reduce this risk and assess the long term ramifications of mitigation and regulatory changes.

Current city floodplain regulations do not prevent redevelopment of these properties but require suitable flood protection measures and allow structural mitigation of high hazard and conveyance zone impacts. Although redevelopment of these properties would secure flood protection under the 100-year flood event, these properties would still be subject to flood damage from larger flood events. Redevelopment of some of these properties could also result in further structural mitigation of high hazard and conveyance zone impacts or reduce the likelihood of redevelopment in key commercial areas such as the North Boulder Village Center. The Flood Hazard Land Use Analysis will explore a range of strategies to reduce the flood risk in flood prone areas and clarify and strengthen the city's flood management policies.

The analysis will inform recommendations to changes in flood plain policies and regulations. This study effort will likely begin in 2010 or 2011.

Question #2: Does council have questions about current flood policies and how they are being applied in the Fourmile Canyon Creek and Wonderland Creek Flood Mitigation Plan?

B. Critical Facilities and Vulnerable Populations

Prevention and mitigation of flood damages to critical facilities and life safety issues associated with at-risk populations are important issues in prioritizing flood mitigation capital improvement projects. In an effort to reduce the damages to infrastructure and strengthen life safety responses, city staff is developing and analyzing preliminary, draft regulations pertaining to critical facilities and vulnerable populations located in the 100-year and 500-year floodplains. These preliminary, draft regulations include the following definition of critical facilities:

“Critical facility,” for floodplain purposes, means a facility, including without limitation, a structure, infrastructure, property, equipment or service, that if flooded may result in severe consequences to public health and safety or interrupt essential services and operations for the community at any time before, during and after a flood. A critical facility is classified by the following categories: (1) Essential Services, (2) Hazardous Materials, (3) At-risk Populations, and (4) Vital to Restoring Normal Services.

In addition to attempting to define critical facilities, staff is also developing management strategies for these facilities that will strengthen life safety emergency preparedness and reduce, over time, the type and number of facilities exposed to flood risk. Staff anticipates completing the analysis of the preliminary, draft regulations, along with identifying the impacts, and initiating a public review and comment process within the next six months. Please see **Attachment E** for more information on the development of the critical facility regulation.

Staff conducted research on the number and locations of facilities that would be classified as critical. The following table presents the number of critical facilities along each drainageway for the high hazard zone, conveyance zone, and 100- year floodplain.

Critical Facilities Located in the High Hazard and Conveyance Zones

High Hazard Zone Facilities

Name	Address	Primary Category	Second Subcategory
Cottage School	1301 North Street	At-risk Population	Day Care
Dream Makers Preschool	1345 28th Street	At-risk Population	Day Care
Crestview Christian Reformed	3545 Madison Ave	At-risk Population	Church
*New Britain Building	1101 Arapahoe Ave	Essential Services	Warning Systems
*Boulder Fire Station # 3	30th & Arapahoe	Essential Services	Warning Systems
*Boulder Fire Station # 3	30th & Arapahoe	Essential Services	Fire
*New Britain Building	1101 Arapahoe Ave	Vital Normal Services	Administration and Management
Atrium Building	1300 Canyon Blvd	Vital Normal Services	Administration and Management
Boulder Building Maintenance	1720 13th St	Vital Normal Services	Maintenance and Equipment
Park Central Building	1739 Broadway	Vital Normal Services	Permitting and Inspection

Conveyance Zone Facilities

Name	Address	Primary Category	Second Subcategory
Elm Tree	1330 Alpine Ave.	At-risk Population	Day Care
Wynwood at Ridge Point	3375 34th St.	At-risk Population	Senior Housing
Millennium Harvest House	1345 28th St	At-risk Population	Hotel
Alandi Ashram	1705 14th St	At-risk Population	Church
St. Andrew Church	3700 Baseline	At-risk Population	Church
Cottage School Day Camp	805 30th Street	At-risk Population	Day Care
CU Married Student Housing	Marine St	At-risk Population	Student Housing
Boulder Medical Center	2750 Broadway	Essential Services	Clinic
Crossroads AMOCO	3005 Arapahoe Ave	Hazardous Materials	Service Station
Grizzly Gasoline and Store	3200 Arapahoe Ave	Hazardous Materials	Service Station
Conoco	601 S. Broadway	Hazardous Materials	Service Station
Boulder Municipal Building	1777 Broadway	Vital Normal Services	Administration and Management
Downtown Public Library	900 Canyon Blvd	Vital Normal Services	Library

*In the table above, some structures may include more than one type of critical facility category. For example, the New Britain Building includes both a flood warning system and city administration and management services. The general location of critical facilities located in the high hazard zone and conveyance zones is shown on the map of **Attachment F**.

Critical Facilities Located in Flood Hazard Areas

Major Drainageway	High Hazard and Conveyance Zone Structures	100 Year Floodplain Structures	Drainageway Total
Boulder Creek	13	35	48
Fourmile Canyon Creek	0	2	2
Twomile Canyon Creek	0	4	4
Goose Creek	3	4	7
Elmer's Twomile Creek	0	2	2
Gregory Canyon Creek	0	3	3
Skunk Creek	2	4	6
Bear Canyon Creek	2	2	4
South Boulder Creek	0	4	4
Wonderland Creek	1	4	5
Sunshine Canyon Creek	0	0	0
Bluebell Canyon Creek	0	0	0
King's Gulch	0	0	0
Dry Creek	0	0	0
Totals	21	64	85

These high hazard and conveyance zone critical facilities are further identified as follows:

Fourmile Canyon and Wonderland Creeks

There are currently seven critical facilities located in the Wonderland and Fourmile Canyon Creek 100-year floodplains. Five of these facilities house vulnerable populations. The proposed flood mitigation plan would remove three critical facilities from the 100-year floodplain and one facility from the conveyance zone.

Critical Facilities - Fourmile Canyon and Wonderland Creeks

Name	Address	Drainageway	Relationship to Flood Condition					
			Existing Conditions			Phase A Mitigation Measures		
			100	Con	HHZ	100	Con	HHZ
Crestview Elementary	1897 Sumac Ave	Fourmile	Within	outside	outside	no change	no change	no change
Shining Mountain Waldorf School	999 Violet Ave	Fourmile	within	outside	outside	no change	no change	no change
Boulder Waldorf Kindergarten	4072 N. 19th	Wonderland	within	outside	outside	no change	no change	no change
The Atrium: Brookdale Senior Living	3350 30th St.	Wonderland	within	outside	outside	removed	no change	no change
Wynwood at Ridge Point	3375 34th St.	Wonderland	within	within	outside	removed	removed	no change
Diagonal AMOCO Gas	2990 Diagonal Hy	Wonderland	within	outside	outside	removed	no change	no change
N. Broadway Silco Gas	4501 N Broadway	Fourmile	within	outside	outside	no change	no change	no change

Key to above table: “100” means within the 100-year floodplain
“Con” means within the conveyance zone
“HHZ” means within the high hazard zone

With respect to these facilities the proposed critical facilities regulation management strategies will regulate facilities that provide care for 12 or more children/students/residents. Upon change of use, new use or expansion, these facilities will develop an emergency management plan that will at a minimum include either an evacuation plan or a shelter in place plan. For the two facilities that store hazardous chemicals, upon change of use, new use, or substantial modification or improvement, all hazardous material must be stored such that they are located above the 500-year flood elevation or are floodproofed.

Staff was asked to investigate the specific emergency plan for Crestview Elementary School. The proposed flood mitigation plan for this school would not eliminate it from the 100-year floodplain. City staff have contacted Boulder Valley School District (BVSD) staff and discussed the best way to deal with a flood emergency for schools in Boulder. Evacuation may be the best approach in cases where there is adequate advanced warning of certain types of flood events that develop slowly due to extended periods of low-intensity rainfall. However, advanced warning may be too short or not possible for flash flood events. The existing Crestview Elementary School building structure would provide substantial protection during a flood event, so shelter in place should be considered versus the risk of exposing evacuees directly to flood waters. During a major flood event, it is likely that the first floor of the building would be partially flooded. Evacuation to the roof is a possibility but problematic during inclement weather conditions. It has been recommended to the BVSD staff that they consider flood proofing the existing structure to minimize the entry of water. As indicated previously, the proposed plan would improve the ability of emergency response personnel to access and egress the flooded areas along Fourmile Canyon and Wonderland creeks including those associated with Crestview Elementary School. This information has been discussed with BVSD/Central Administration staff and Crestview Elementary School administration staff, but a full and complete resolution and consensus regarding the best action has not been reached. City staff, Boulder County Emergency Management staff and BVSD staff will continue the conversations so that ultimately, the BVSD can implement an emergency management and response plan for the students, faculty and parents.

In addition, city stormwater/flood education staff has been in contact with Crestview faculty and are sharing flood preparedness education information with teachers and students. The 5th graders from Crestview will be attending the city's annual Children's Water Festival in May, which will contain a flood education component. Outreach materials are being shared with other schools in Boulder as well.

Question #3: What feedback does council have regarding the development and analysis of preliminary, draft regulations pertaining to critical facilities and vulnerable populations located within the 100-year and 500-year floodplains?

C. Property Damage and Other Cost Issues

In the event of a significant flood, property damage will be considerable. In addition, a major flood on Boulder Creek may have a major impact on Boulder's economy since much of Boulder's commercial and industrial property is located in the Boulder Creek floodplain. For

these reasons, mitigation of potential property damage due to floods is also considered in prioritizing flood mitigation capital improvement projects.

The following information is presented concerning the number of structures and assessed value for each major drainageway. Based on this information, approximately 11 percent of the structures representing eight percent of the assessed value in the 100-year floodplain are associated with Fourmile Canyon and Wonderland creeks.

Number and assessed value of structures located in the 100-year floodplain

Drainageway	Number of Structures	Assessed Value
Boulder Creek/Boulder Slough	935	\$ 590,684,000
Fourmile Canyon	144	\$ 38,362,200
Wonderland	361	\$ 109,125,900
Two-mile Canyon	208	\$ 52,874,400
Goose	210	\$ 101,439,300
Elmer's Twomile	150	\$ 44,415,100
Sunshine Canyon	87	\$ 30,387,500
Gregory Canyon	127	\$ 47,789,200
South Boulder/Dry Creek No. 2	1,063	\$ 429,561,100
Skunk	200	\$ 65,842,900
Bluebell/Kings Gulch	43	\$ 13,003,400
Bear Canyon	93	\$ 34,744,400
Viele	0	\$ 0
Totals	3,621	\$ 1,558,229,400

Flood insurance provides a mechanism for private property owners to mitigate some of the potential property damage due to flooding. However, the maximum insurable value under FEMA's National Flood Insurance Program (NFIP) is \$250,000.

Economic impacts from floods to property and business owners may also be mitigated to some degree by federal disaster assistance programs. These programs provide relief funding to communities who suffer a major disaster so that the community can rebuild its economy and tax base.

In determining whether to acquire property and/or use other flood mitigation alternatives, a traditional cost-benefit analysis is used to compare the current value of future flood losses with the cost of project improvements. For example, along certain segments of Fourmile Canyon and Wonderland creeks, the estimated benefit-cost ratio of implemented pre-flood improvements is greater than five. In these cases, staff is recommending that the city initiate improvements that would alleviate damages caused by a 100-year flood. An alternative approach would be for the private property owners to continue to bear the cost of maintaining flood insurance through the NFIP.

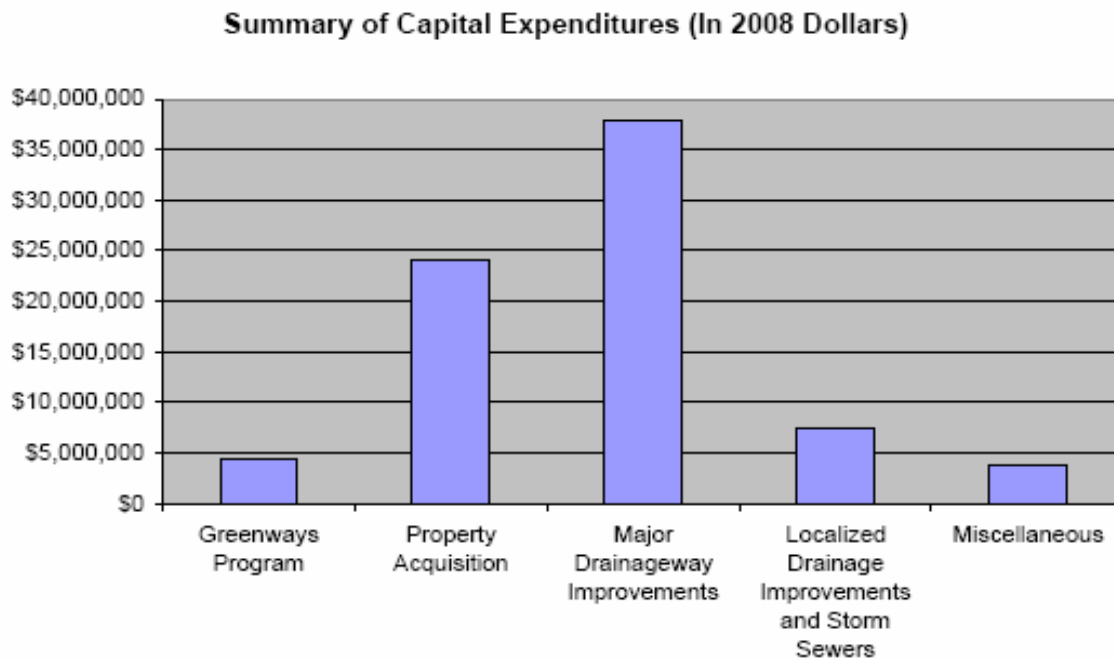
There is also the potential of property damage to city infrastructure such as roadways and utility pipes.

Fourmile Canyon and Wonderland Creeks

From a property damage perspective, 11 percent of the structures representing eight percent of the assessed value in the 100-year floodplain are associated with Fourmile Canyon and Wonderland creeks. The proposed flood mitigation plan would significantly mitigate the potential for property damage. The current value of mitigating future property damage due to flooding has been estimated to be greater than \$90 million.

The overall cost of the proposed property acquisition and flood mitigation plan is significant, but would be implemented over a period of several decades depending on the ability of the city to fund the improvements. Acceptance of the study does not obligate the city to fund the proposed flood mitigation improvements. Specific funding requests are prioritized and submitted through the annual budget process.

The following chart summarizes the city's Stormwater and Flood Management Utility capital expenditures from 1990 through 2008 in units of 2008 dollars. Over \$24 million has been spent on pre-flood property acquisition and nearly \$38 million on major drainageway (flood mitigation) improvements. The largest expenditures were associated with Goose Creek (\$19 million) and Boulder Creek (\$15 million).



Localized drainage improvements include small storm sewers (up to 36-inch diameter) and street inlets to convey small quantities of stormwater.

The estimated costs associated with the proposed flood mitigation plan recommended by staff are as follows:

Proposed Present Worth Costs in 2008 dollars

City Capital Costs

Property acquisition	\$4 to 6 million
Channel improvement	\$10 to 12 million
Roadway crossing	\$8 to 10 million
City On-going Operation and Maintenance	\$5 to 6 million

Private Property Owner Costs

Floodproofing	\$15 to 20 million
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In many cases, the cost of the proposed improvements can be shared with other agencies including the UDFCD and the city's Transportation Division. The plan proposes significant capital improvement expenditures associated with combination flood conveyance and pedestrian underpasses at major roadways. Typically, these costs have been split between the city's Utilities and Transportation divisions. In some cases, these projects have been partially funded by the Federal Transportation Improvement Program.

The level of capital expenditure needed to accomplish the flood mitigation along Fourmile Canyon and Wonderland creeks is deemed reasonable, considering the length of time over which the work would be accomplished. The suggested improvements are consistent with the level of previous flood mitigation expenditures by the city's Stormwater and Flood Management Utility.

D. Collaboration with Greenways Program Objectives

The initial Tributary Greenways Master Plan that was developed in 1989 described the purpose of the program as providing a unique opportunity for creating a comprehensive greenways system for the community that could be creatively developed to function as storm drainage and flood channels, efficient bicycle and pedestrian transportation systems, open space and wildlife corridors and attractive recreation areas. The Greenways Master Plan was updated in December 2001. At that time, the purpose of the program was re-evaluated and a purpose statement was developed, which is:

“To extend the stewardship of the city of Boulder to the important riparian areas along the tributaries of Boulder Creek to integrate the following six objectives: protect and restore habitat, enhance water quality, facilitate storm drainage and mitigate floods, provide alternative transportation routes for pedestrians and bicyclists, provide recreational opportunities and protect cultural resources.”

The Greenways Program provides an opportunity to collaborate on various city interests, as well as leverage funding sources. The Greenways Program has adopted an opportunistic approach to achieve multiple objectives throughout the system. Frequently, specific efforts within a

greenway corridor can be completed in conjunction with a transportation, flood hazard mitigation, park or private development project. Major outside funding from such sources as the UDFCD and the Colorado Department of Transportation (CDOT) has allowed the Greenways system to expand and complete projects at an accelerated rate, with a much lower direct cost to the city (nearly 50 percent less). Cooperation with the University of Colorado and the Boulder Valley School District has resulted in extension of greenways facilities through properties owned and managed by those entities. Through the site review process, private developers may provide conservation easements to the city along the program tributaries, as well as fund and construct trail links, park connections and underpass installations.

The Elmer's Twomile Greenways project provides a current example of an opportunity to meet multiple objectives through leveraged funding. The Elmer's Twomile project includes:

- A transportation component that provides a missing link between the Goose Creek Path and Glenwood Drive by constructing a grade-separated path with an underpass at Valmont Road, and
- Flood mitigation improvements that address flooding that occur south of Glenwood Drive during a 100-year storm event. Several properties are currently in the 100-year conveyance zone and portions of these properties are also in the high hazard zone.

The Elmer's Twomile project will result in approximately 50 properties no longer being in the 100-year floodplain. Commercial properties along 28th Street will be removed from the floodplain allowing greater redevelopment potential and providing economic vitality to the city. For example, the Rayback property was purchased and is being redeveloped to take into consideration the improvements made possible by the Elmer's Twomile project.

In addition to providing flood and transportation improvements, the project also includes an enhancement to water quality. As part of this project, the city purchased a one-acre easement that will allow for an open channel and a constructed wetland in a narrow urbanized corridor.

The total cost for the Elmer's Twomile Greenways project from Goose Creek to Glenwood Drive including design, property acquisition and construction is estimated to be \$9 million. The Elmer's Twomile project is being funded through the city's Stormwater and Flood Management Utility (\$3.47 million) and Greenways CIP (\$1 million), with additional funding contributions from outside sources including the Federal Transportation Improvement Program (\$3.25 million) and the Urban Drainage and Flood Control District (\$1.28 million). By collaboratively constructing projects like the Elmer's Twomile Greenways project, the city can leverage outside funding and share in costs that would be required if the projects were bid out separately.

Fourmile Canyon and Wonderland Creeks

The proposed flood mitigation plan for Fourmile Canyon and Wonderland Creeks provides many opportunities to collaborate with other Greenways Program projects including transportation, recreation, environmental and water quality enhancements. The Greenways Master Plan ranked the opportunity for improvements for each of the Greenways' objectives by stream reach. For the reaches of Fourmile Canyon Creek west of 28th Street, the need for a path connection ranked high, primarily as it serves as a "safe route to school" for the Crestview Elementary School students. Habitat and water quality improvements received a medium ranking throughout

Fourmile Canyon Creek based on opportunities to improve the quality of the habitat in these areas. Along Wonderland Creek, between Foothills and 28th Street, the transportation objective received a medium ranking. Habitat and water quality opportunities received a medium to high ranking for the most part along Wonderland Creek. These improvements were considered and incorporated as part of the proposed flood mitigation plan.

Question #4: What feedback does council have regarding the proposed Fourmile Canyon Creek and Wonderland Creek flood mitigation plan regarding costs, benefits and priorities?

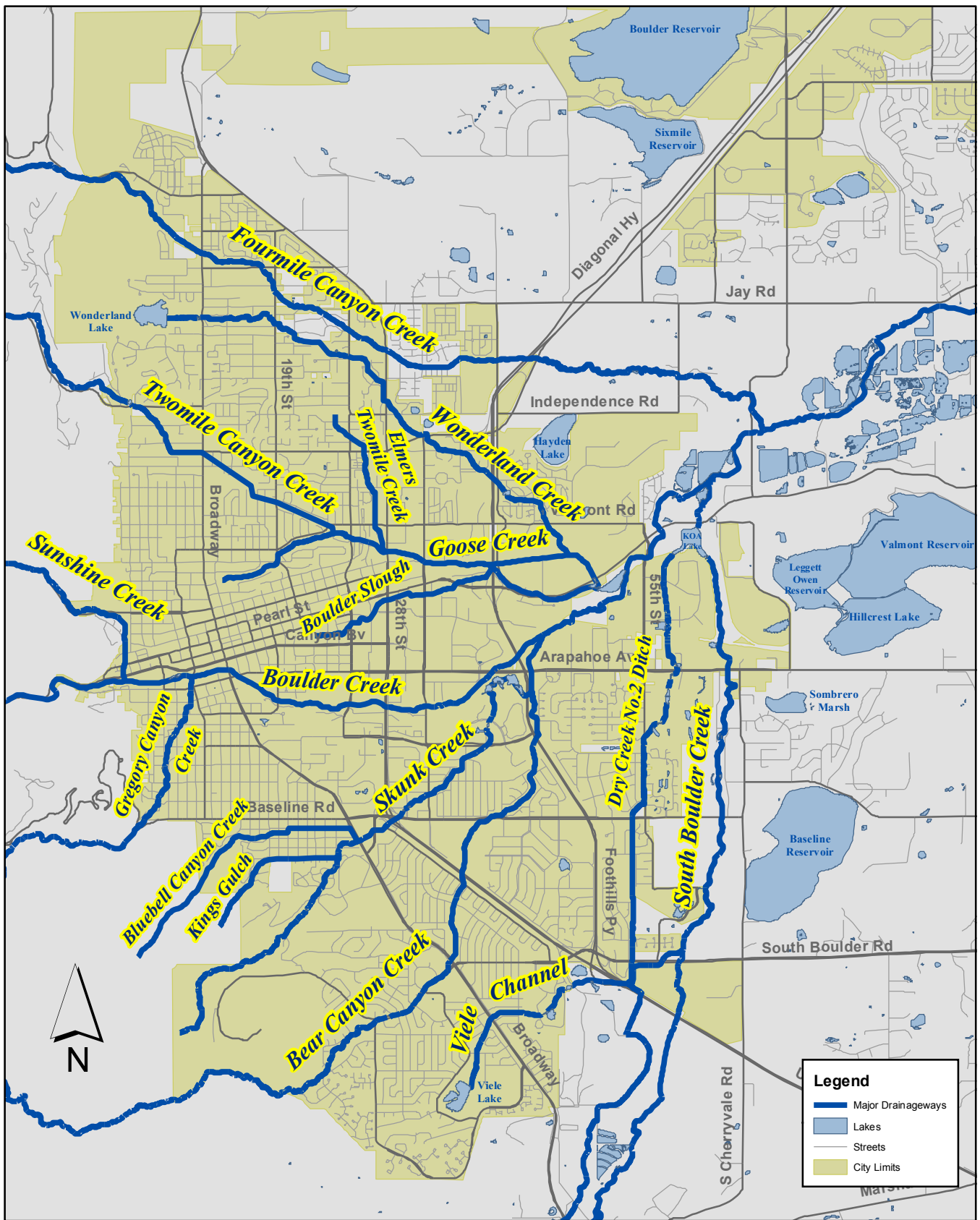
IV. Next Steps

As part of this study session packet, staff has presented additional information regarding the issues raised by council in the previous Nov. 10, 2008 public hearing. As next steps, staff will:

1. Prepare an agenda item to accept the Study Session summary,
2. Prepare an agenda item to consider acceptance of the proposed Fourmile Canyon Creek and Wonderland Creek flood mitigation plan, and
3. Continue the development and analysis of the preliminary, draft regulations pertaining to critical facilities and vulnerable populations located within the 100-year and 500-year floodplains, along with identifying the impacts, and initiating a public review and comment process within the next six months.
4. Develop a Flood Hazard Land Use Analysis to explore a range of strategies for reducing the flood risk in flood prone areas. The analysis will inform recommendations to changes in flood plain policies and regulations and will likely begin in 2010 or 2011.

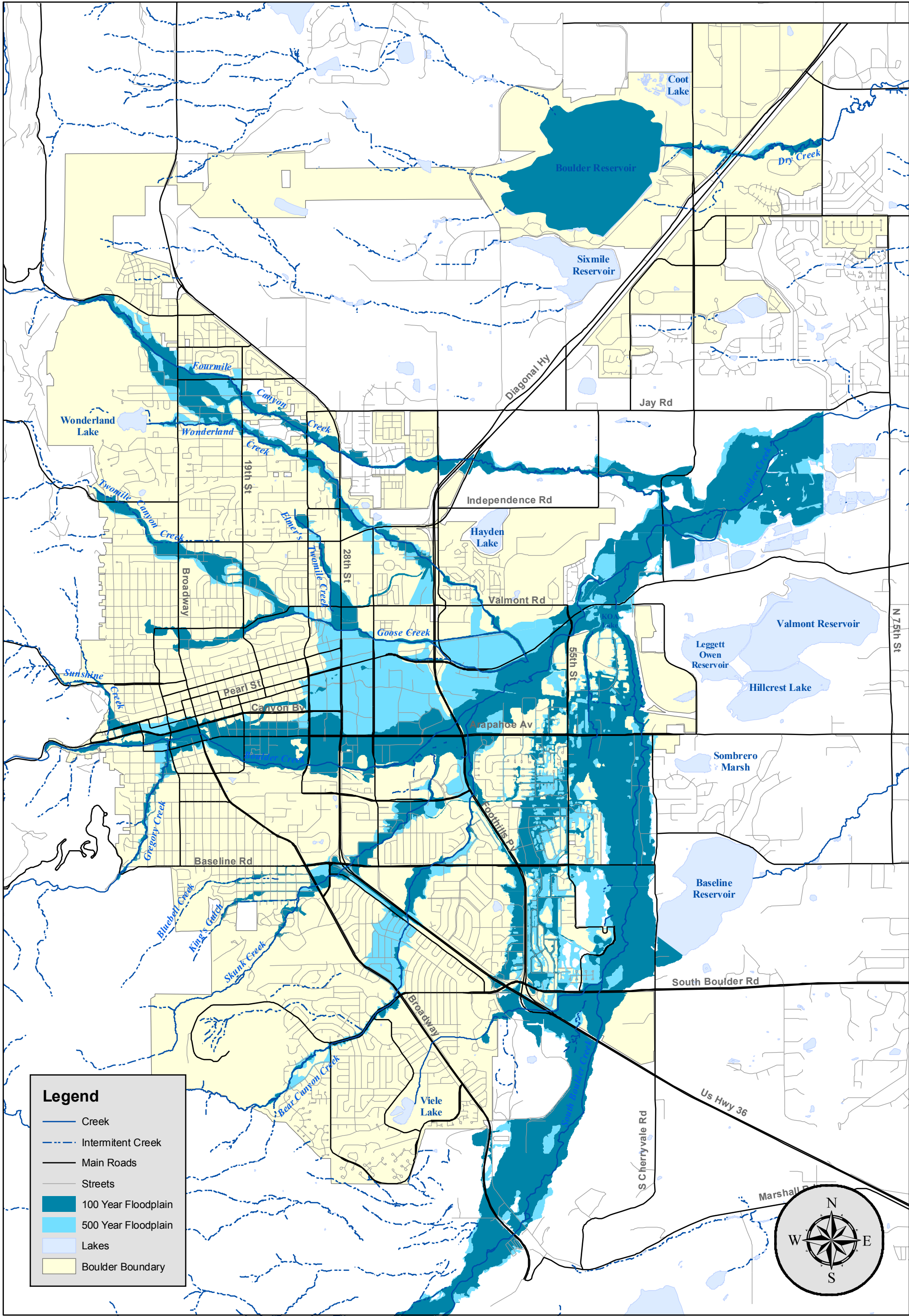
Question #5: Does council have questions regarding the proposed next steps for either the Fourmile Canyon Creek and Wonderland Creek flood mitigation plan or the draft regulations pertaining to critical facilities and vulnerable populations?

The End



City Of Boulder

Major Drainageways



Attachment B



City Of Boulder
100 & 500 Year
Floodplains

**CITY OF BOULDER
CITY COUNCIL AGENDA ITEM**

MEETING DATE: November 10, 2008

AGENDA TITLE: Consideration of a Motion accepting the Fourmile Canyon and Wonderland Creeks Flood Mitigation Plan as documented in the Phase A Report and as Modified by Staff

PRESENTERS

Jane S. Brautigam, City Manager
Stephanie Grainger, Deputy City Manager/Operations
Maureen Rait, Executive Director for Public Works
Ned Williams, Director of Public Works for Utilities
Bob Harberg, Utilities Planning and Project Management Coordinator

EXECUTIVE SUMMARY:

The purpose of this agenda item is for City Council's review and consideration of a flood mitigation plan for Fourmile Canyon and Wonderland creeks in north Boulder.

The Fourmile Canyon Creek and Wonderland Creek Major Drainageway Planning - Phase A Report - Alternatives Analysis was developed by Love & Associates, dated June 2007. The Phase A Report focuses on the development, evaluation, and recommendations of flood mitigation alternatives along both creeks. The work was jointly sponsored by the Urban Drainage and Flood Control District (UDFCD) and the city. The executive summary of the Phase A Report is presented as **Attachment A**.

City staff has coordinated this flood mitigation planning effort with the objectives of the city's Greenways Program. A public process that included two open houses and several public hearings with the Water Resources Advisory Board (WRAB) and Planning Board was conducted. Based on the feedback received during this process, several flood mitigation alternatives were evaluated and refined. A chronology of the flood mitigation planning, including the public process, is presented as **Attachment B**. A map of the study area is included as **Attachment C**.

The complete Fourmile Canyon Creek and Wonderland Creek Phase A Report is available at the City Council Office and the main branch of the Boulder Public Library and on the city's Web site at www.boulderwater.net under "Projects & Programs."

STAFF RECOMMENDATION:

Suggested Motion Language:

Staff requests council consideration of this matter and action in the form of the following motion:

Motion to accept the Fourmile Canyon Creek and Wonderland Creek Flood Mitigation Plan as documented in the Phase A Report (**Attachment A**) and as modified by the staff recommendations documented in this agenda item.

Staff recommendations for each of the various sections of the creeks can be found in the “Analysis” section of this memo and a summary table of the staff recommendations is found at the end of the section.

COMMUNITY SUSTAINABILITY ASSESSMENTS AND IMPACTS:

Economic: A land use analysis associated with the recommended mitigation plan shows that the proposed mitigation work allows for redevelopment consistent with the North Boulder Subcommunity Plan. Thus, mitigation work should help enhance the economic viability of the north Boulder community.

Environmental: Flood mitigation work is intended to create as little environmental disturbance as possible. In particular, through discussions with residents during the public process, the Githens Acres riparian corridor was re-studied in order to minimize environmental impacts from flood mitigation work. Additionally, as seen with redevelopments such as the Violet Crossing on Fourmile Canyon Creek, flood mitigation work can result in the expansion of wetlands and provide water quality enhancements.

Social: In addition to environmental upgrades, mitigation work also includes Greenways Program objectives such as improved trails and educational opportunities in the riparian corridor that provide benefit to the entire community.

OTHER IMPACTS:

Fiscal: The flood mitigation plan recommended by staff is estimated to have a total cost of \$49,253,000 of which \$33,926,000 would be a public expense and \$15,327,000 would be borne by private property owners. The city’s project funding would be supplemented by the Urban Drainage and Flood Control District (UDFCD), who routinely participates in flood mitigation efforts. Property owners would not be required to bear their expense unless they proposed new development or redevelopment on their property, in which case, they would be required to meet current flood-proofing regulations. Rather, property owners would be encouraged to protect their property from future flood damages through voluntary efforts by flood proofing their individual structures.

The plan will likely take several decades to implement by the city. Significant total benefits of over \$90,000,000 are estimated based on a reduction in total property damage due to future flooding. The following Table summarizes the cost and benefit information based on a present worth cost analysis (2007 dollars) using a 50-year period and a discount rate of 3 percent. The cost analysis does not consider insurance premium, life safety or greenways benefits.

Wonderland Creek						
Reach	Staff Recommended Alternate	B/C Ratio	Benefits	Costs		
			Total	Total	Public	Private
1	Maintain Existing	0.00	\$0	\$618,000	\$618,000	\$0
2	Floodproofing	0.60	\$326,000	\$539,000	\$332,000	\$207,000
3	HHZ Containment/ Floodproofing	0.47	\$4,803,000	\$10,237,000	\$7,307,000	\$2,930,000
4	100-Year Channel	5.34	\$37,970,500	\$7,110,000	\$7,110,000	\$0
5	100-Year Channel	4.75	\$19,279,300	\$4,058,000	\$4,058,000	\$0
6	HHZ Containment/ Floodproofing	0.37	\$1,601,200	\$4,365,000	\$2,509,000	\$1,856,000
7	Maintain Existing	0.00	\$0	\$807,000	\$807,000	\$0
8	Maintain Existing	0.00	\$0	\$289,000	\$289,000	\$0
Total		2.28	\$63,980,000	\$28,023,000	\$23,030,000	\$4,993,000

**Fourmile Canyon
Creek**

Reach	Staff Recommended Alternate	B/C Ratio	Benefits	Costs		
			Total	Total	Public	Private
1a	HHZ Containment/ Floodproofing	0.50	\$785,600	\$1,584,000	\$1,025,000	\$559,000
1b	Maintain Existing	0.00	\$0	\$1,188,000	\$1,188,000	\$0
2a	Maintain Existing	0.00	\$0	\$442,000	\$442,000	\$0
2b	100-Year Channel	2.15	\$3,402,400	\$1,580,000	\$1,580,000	\$0
3	HHZ Containment/ Floodproofing	0.65	\$585,400	\$900,000	\$741,000	\$159,000
4	HHZ Containment/ Floodproofing	1.22	\$11,160,000	\$9,113,000	\$4,468,000	\$4,645,000
5	HHZ Containment/ Floodproofing	4.02	\$3,209,000	\$798,000	\$394,000	\$404,000
6a	HHZ Containment/ Floodproofing	1.12	\$5,274,000	\$4,689,000	\$290,000	\$4,399,000
6b	HHZ Containment/ Floodproofing	3.62	\$2,761,000	\$763,000	\$595,000	\$168,000
6c	Maintain Existing	0.00	\$0	\$173,000	\$173,000	\$0
Total		1.28	\$27,177,400	\$21,230,000	\$10,896,000	\$10,334,000
Combined Total		1.85	\$91,157,400	\$49,253,000	\$33,926,000	\$15,327,000

Funding has been budgeted for the proposed flood mitigation work in the 2009-2014 Utilities Division Capital Improvement Program (CIP) budget. The proposed work is comprised of multiple individual projects that allow funding to be spread out over the next 20-30 years. The city will prioritize those projects that have the most significant benefit from either a life safety or property damage mitigation perspective and are within the incorporated city limits. Projects that provide multiple benefits and allow the city to leverage funding with private developers or other agencies such as the Denver Regional Council of Governments (DRCOG) Transportation Improvement Project (TIP) funding will also be prioritized. One of these projects is envisioned to be a new culvert and pedestrian underpass at the Burlington Northern and Santa Fe Railroad and Boulder White Rocks Ditch just upstream of Foothills Parkway on Wonderland Creek. The city applied for TIP funding for this project and it is possible the city will receive matching funds. All projects will be closely coordinated with the city's Greenways Program and Transportation Division.

As a result of some of the recommended mitigation alternatives, there are a significant number of flood insurance policy holders who in the future would no longer be required to hold flood insurance with their mortgages. It is estimated that a combined property owner premium savings of approximately \$225,000 per year would be realized if the outlined mitigation recommendations were implemented. In addition, a primary goal has been to remove structures from the high hazard zone (HHZ) to eliminate life-safety risk. The implementation of the improvements would remove all structures along both creeks from the HHZ with the exception of a few storage sheds and garages. Below is a table listing the total annual premium savings for each reach.

Wonderland Creek				
Reach	# Structures in 100-year Floodplain	# Structures Removed from 100-year Floodplain	Total Annual Premium under Existing Conditions	Savings after Implementation of Selected Alternate
1	0	0	\$0	\$0
2	16	0	\$20,800	\$0
3	82	82	\$77,800	\$77,800
4	5	5	\$8,700	\$8,700
5	70	70	\$67,300	\$67,300
6	19	3	\$17,600	\$735
7	3	0	\$2,600	\$0
8	1	0	\$200	\$0
Total	196	160	\$195,000	\$154,535

Fourmile Canyon Creek				
Reach	# Structures in 100-year Floodplain	# Structures Removed from 100- year Floodplain	Total Annual Premium under Existing Conditions	Savings after Implementation of Selected Alternate
Lower	18	0	\$8,100	\$0
1	0	0	\$0	\$0
2	7	7	\$3,700	\$3,700
3	4	0	\$4,200	\$0
4	29	29	\$40,400	\$40,400
5	59	0	\$66,600	\$0
6	22	14	\$34,500	\$26,315
Total	139	50	\$157,500	\$70,415

Staff time:

Staff is intending to work with consultants to develop future phases of this mitigation project. This will be built into yearly work programs.

BOARD AND COMMISSION FEEDBACK:**Greenways Staff and Greenways Advisory Committee (GAC):**

Project staff met with Greenways staff and the Greenways Advisory Committee (GAC) on Sept. 19, 2007. The proposed flood mitigation plan followed the recommendations of the Greenways Master Plan with regard to all of the objectives of the Greenways Program including the use and location of multi-use paths, as well as habitat restoration recommendations. The GAC concluded that there should be continued focus on minimizing the HHZ, including perhaps considering property damage as a less important factor for Reach 4 of Fourmile Canyon Creek in exchange for fewer impacts on the drainage area. Top priorities identified by the GAC were: high hazard mitigation and undersized culvert replacement and flood protection. Greenways staff were directed to work to establish environmental criteria for flood project construction.

Water Resource Advisory Board (WRAB):

Discussions with the WRAB occurred on Oct. 15, 2007, Dec. 17, 2007 and Jan. 28, 2008. WRAB recommended that City Council accept the flood mitigation plan based on the following motion:

Motion: Recommend approval of the Phase A plan as modified by staff with the following recommendations and guiding principles as this project continues to future phases and more detailed concept review (Approved vote 4-0, 1 absent).

The complete WRAB recommendations and guiding principles, along with staff responses, is presented as **Attachment D.**

Planning Board:

The proposed flood mitigation plan was presented to the Planning Board on Feb. 21 and March 20, 2008. The purpose was to provide Planning Board with information regarding the land use implications of the proposed flood mitigation plan. Planning Board recommended that City Council accept the flood mitigation plan based on the following motion:

Motion: The Planning Board recommended (5-1, A. Sopher opposed, R. Sosa absent) that City Council accept the proposed flood mitigation plan outlined in the March 20, 2008 staff memorandum including the following additional recommendations:

- 1. That City Council approve the staff's recommendation with prioritization, to the extent feasible from an engineering perspective, favoring city improvements over county improvements;*
- 2. That public education on life safety issues as to flooding, particularly as to critical facilities, be given a high priority;*
- 3. And that discussion with the affected property owners in the Village Center take place with the feasibility of moving forward with flood mitigation.*

The dissenting vote from Sopher was based on his request that the report contain additional physical flood protection for access and egress to Crestview Elementary and Waldorf Elementary school. Staff has met with the Waldorf School officials and is working with Crestview to educate them on flood awareness and response. Sopher felt that education was not enough to ease flood concerns. Staff indicated the plan does call out replacement of underpasses at Violet, Upland, 19th at Fourmile and 19th at Wonderland. Through the increase in conveyance of flood flows, these underpasses would allow passage on roadways over the creeks in a 100-year flood.

PUBLIC FEEDBACK:

The public process for this study has included a presentation to the GAC, WRAB and Planning Board. At each event, the public had an opportunity to give input and their comments have been noted and responded to as follows:

During the December 2007 WRAB meeting, a question was raised whether detention storage was feasible for upstream Fourmile Canyon Creek in order to mitigate the spill to Wonderland Creek. The consultant was asked to consider this option and provide an analysis. The consultant determined that a 30-acre footprint multi-staged reservoir would be required in addition to significant channel work. The cost was estimated at \$55,000,000. Because of the significant environmental impacts of this approach and the excessive project costs, staff does not recommend this option.

Also during the December 2007 WRAB meeting, a suggestion by several members of the public was made to use the area of undeveloped land north of Violet to direct flood flows east to the U.S. 36 corridor and then over to Boulder Creek. Such an alignment could remove water from the main stem of Fourmile Canyon Creek, including the spill flow under the 100-year flood event, and redirect this flow to Boulder Creek through a man-made conveyance structure. The estimated cost of this alternative is approximately \$53 million. This project would present substantial property acquisition issues as well as other impacts along the corridor, many of which would impact city Open Space land.

A question that has come up numerous times is why the Fourmile Canyon Creek flood flows are not contained in the channel, thereby lessening the impact to Wonderland Creek. An underlying issue with regard to the conceptual analysis is how to mitigate the historic spill flows that move from Fourmile Canyon Creek to Wonderland Creek in events exceeding the 50-year recurrence interval. The spill from Fourmile is due to the topography and has historically occurred. Changing historical flow patterns has enormous implications and is traditionally avoided. If containment was initiated, a great deal of mitigation work would have to be completed on Fourmile since the existing facilities and flood protection is sized for the historical lower flow rates. All of these costly projects would have to be completed before any diversion could occur. Additionally, there are a number of legal issues associated with changing flood patterns of this magnitude and UDFCD has indicated that they would not support this concept. The UDFCD legal opinion is available as **Attachment E**.

Even with the great deal of flood mitigation improvements suggested with this study, there will still be areas of shallow flooding, most notably in the spill area between Fourmile Canyon and Wonderland creeks. Citizens living within these areas have raised concerns with regard to property damage and the cost of flood insurance. However, these areas do not pose the same life safety and property damage threats that are posed by the flood hazard zones along the main channels of Fourmile Canyon and Wonderland creeks. It is proposed that the city's resources be directed towards flood mitigation work that addresses the most significant life safety and property damage issues. A limited amount of funding is available to address other repetitive loss drainage issues, and citizens will be encouraged to come forward with drainage concerns in order for the city to prioritize and attempt to mitigate these problems.

Finally, a comment was received regarding completing the plan but questioning why implementation of mitigation projects has to occur before a flood event. Staff feels that the risk to life safety and property compels the city to attempt to pursue mitigation projects prior to an actual flood event.

ANALYSIS:

The study area includes the Fourmile Canyon Creek floodplain from the mouth of the canyon to its confluence with Boulder Creek, and the Wonderland Creek floodplain from downstream of Wonderland Lake to its confluence with Goose Creek. Additionally, the Fourmile Canyon Creek spill floodplain, located between Fourmile Canyon Creek and Wonderland Creek, upstream of Broadway approximately to 19th Street, is also included.

Background:

Major drainageway planning documents were previously developed for Fourmile Canyon Creek and Wonderland Creek in the mid 1980s. Due to development that occurred in the floodplain and better floodplain information, the city of Boulder commissioned a re-study of the Fourmile Canyon Creek floodplain and the Wonderland Creek flood hazards. The study is based on detailed 2003 aerial mapping and new hydrologic analysis techniques. Love & Associates was retained by the city to prepare a Letter of Map Revision (LOMR) submittal to FEMA for these two streams. The LOMR was developed during 2004-2005 and approved by various city boards and the City Council in early 2006. The LOMR was submitted to FEMA in March 2006 and approved in November 2006. The new flood hazard areas became official following the end of the public appeal period in late March 2007.

The initial flood mitigation planning effort began in June 1999. Both a Phase A and Phase B study were completed for Fourmile Canyon Creek. However, it became apparent that the topography has historically caused a wide shallow spill from Fourmile Canyon Creek to Wonderland Creek. It was decided that historic flows should not be altered and UDFCD advocated there be no changes to existing drainage patterns. Following the review and input from an Independent Review Panel (IRP) comprised of floodplain experts in 2000, it was recommended that due to the interaction of the creeks, a combined Phase A alternate analysis report should be undertaken for both Fourmile Canyon and Wonderland creeks. Subsequent to the completion of the LOMR, the combined alternate analysis began in fall 2006. The final Phase A report was published in June 2007.

The flood analysis of Fourmile Canyon and Wonderland creeks indicated significant differences from the original regulatory studies, resulting in additional properties being located within the two floodplains. Of particular importance, the re-study identified reaches of Fourmile Canyon Creek west of 19th Street, where, once the channel capacity is exceeded, flood flows overtop the south bank of the creek and flow in a southeasterly direction towards Wonderland Creek. These “spill flows” result in a reduction of flows in Fourmile Canyon Creek downstream of 19th Street but also result in an increase in the flows in Wonderland Creek. During the 100-year flood event, Fourmile Canyon Creek near the mouth of the canyon would experience approximately 3,300 cubic feet per second (cfs) of water. Of this amount, approximately 1,600 cfs will overtop the south bank spill and flow toward Wonderland Creek. The remaining 1,700 cfs will remain in the Fourmile Canyon Creek channel. Likewise, the 100-year discharge in Wonderland Creek significantly increases downstream of the spill inflow. Some of the spill returns to Fourmile Canyon Creek near 19th Street, but the majority remains in the Wonderland Creek floodplain.

Early in the study, a broad range of alternates were identified. These alternates were screened following an analysis of each stream and detailed discussions held during progress meetings on a reach-by-reach basis for each stream. A wide array of options were looked at as potentials for mitigation of the flooding, ranging from a status quo alternate to construction of a 100-year storm event containment alternate for each stream, thereby confining the spill from Fourmile Canyon Creek.

Legal Opinion:

There has been some discussion whether the spill from Fourmile Canyon Creek to Wonderland Creek should be contained. This approach would not maintain historic flow patterns. A legal opinion was issued by the Urban Drainage and Flood Control District (UDFCD) recommending against any changes to the historic flow pattern of Fourmile Canyon and Wonderland creeks. Based in part on this legal opinion, containment of 100-year storm event flood water in Fourmile Canyon Creek is not considered a desirable option. Therefore, the flood mitigation plan anticipates that flood water will continue to flow into Wonderland Creek. The legal opinion is presented as **Attachment E**.

Alternatives:

The conceptual alternates considered for both streams included “High Hazard Containment” and “Floodproofing of Structures” alternates. Original alternates considered in the initial Fourmile Canyon Creek Major Drainageway Master Plan also included both a “50- year channel alternate” and “100-year channel alternate.”

- 1) The **100-year flood mitigation alternate** for Fourmile Canyon and Wonderland Creek would be designed by an inter-disciplinary team of engineers, geomorphologists and biologists to emulate a natural channel. This alternate would eliminate various spills from either channel during the 100-year or smaller flood event. The channel would be designed to UDFCD and city criteria with FEMA and city-required freeboard. (Freeboard is the additional elevation built into flood protection as an additional factor of safety.)

- 2) The **50-year flood mitigation alternate** for the study would contain the 50-year flows but would not have freeboard built into the design, in the event of a 100-year flood. The 50-year flood has a 2 percent chance of occurring in any given year.

- 3) The **HHZ containment alternate** would remove all habitable structures identified in either stream from the city's HHZ through direct purchase of the property and physical removal of the building, the enlargement of road crossing structures, channel excavation, and/or floodproofing or a combination thereof. The HHZ is defined as those areas where the product number of velocity (measured in feet per second) times flow depth (measured in feet) equals or exceeds four, or where flow depths equal or exceed four feet. These portions of the 100-year floodplain pose an unacceptably high hazard to human safety. In the HHZ, the construction, expansion or enlargement of any structure intended for human occupancy or establishment of a new parking lot is prohibited. This alternate does not entirely eliminate the out-of-channel bank floodplain; however, it reduces flood levels for structures in the HHZ to increase the safety people who may not be evacuated during a flood. Also, there is increased safety during an evacuation because water levels would be reduced for access and egress. This alternative will also remove the majority of structures from the conveyance zone as indicated in the following table. The table on the following page shows the number of structures removed from the HHZ and Conveyance zone through implementation of the recommended improvements.

WONDERLAND CREEK			FOURMILE CANYON CREEK		
HHZ AFTER RECOMMENDED IMPROVEMENTS			HHZ AFTER RECOMMENDED IMPROVEMENTS		
<u>CITY OF BOULDER</u>	OUT OF HHZ	STILL IN HHZ	<u>CITY OF BOULDER</u>	OUT OF HHZ	STILL IN HHZ
Sub-Total	13	0	Sub-Total	22	1
<u>BOULDER COUNTY</u>	OUT OF HHZ	STILL IN HHZ	<u>BOULDER COUNTY</u>	OUT OF HHZ	STILL IN HHZ
Sub-Total	3	0	Sub-Total	21	3
TOTAL	16	0	TOTAL	43	4
CONVEYANCE ZONE AFTER IMPROVEMENTS			CONVEYANCE ZONE AFTER IMPROVEMENTS		
<u>CITY OF BOULDER</u>	OUT OF CONV.	STILL IN CONV.	<u>CITY OF BOULDER</u>	OUT OF CONV.	STILL IN CONV.
Sub-Total	17	0	Sub-Total	4	3
<u>BOULDER COUNTY</u>	OUT OF CONV.	STILL IN CONV.	<u>BOULDER COUNTY</u>	OUT OF CONV.	STILL IN CONV.
Sub-Total	0	0	Sub-Total	11	3
TOTAL	17	0	TOTAL	15	6

- 4) The **floodproofing alternate** would minimize flood damages by either keeping floodwaters away from damageable property or making the property less susceptible to damages when floodwaters reach the structure. The floodproofing of structures alternate is a combination of adjustments and/or additions of physical features installed in, on or around individual structures and designed to eliminate or reduce the potential for flood damage to the structure. Floodproofing consists of the techniques and approaches for preventing or minimizing flood damages to a structure and its contents in flood hazard areas. Floodproofing techniques include:
- The construction of levees and flood walls around a structure
 - Installing water-tight doors and windows
 - Physically raising the structure elevation using fill or piers
 - Measures designed to reduce water seepage and/or resist lateral pressure from flood water in the structure

Floodproofing measures may be applied to new structures as well as retrofitting existing structures, which may allow for development within the floodplain in low hazard areas. Floodproofing does not eliminate all flood damages but can, if done correctly, significantly reduce damages from flooding. The city may offer guidance and disseminate information regarding various floodproofing techniques; however, it would be the responsibility of the individual property owner to implement this alternate for their own individual properties.

- 5) Alternates proposed were compared to the “**Status Quo**” alternate. Maintaining the existing floodplain configuration would mean adopting the new floodplain mapping without proposing mitigation improvements. Additional non-structural methods, including flash flood forecasting, warning systems and evacuation plans would be recommended for implementation. Flood insurance and floodproofing of structures would also be recommended (at the individual property owner’s expense). Floodplain regulations would be strictly enforced. Post flood relief would be provided. This alternate requires no new city funding, but may sacrifice opportunities to greatly improve Fourmile Canyon Creek and mitigate flooding in the future.

Financial Considerations:

Reach-by-reach cost estimates were prepared for each of the alternates analyzed. The estimate of future flood damage to a property decreases as the level of pre-flood mitigation improvements increase.

One method commonly used to compare alternatives is the benefit/cost (B/C) ratio. In general, the higher the B/C ratio, the more cost effective the alternate. In this study, the benefit/cost ratio compares the total cost to implement a flood control alternate with the benefits that would be realized if that flood control alternate were implemented.

A B/C ratio greater than one (1) indicates the benefit received is greater than the cost to implement the alternative. A B/C ratio equal to one (1) indicates the benefit received is the same as the cost to implement the alternative. A B/C ratio less than one (1) indicates the benefit

received is less than the cost to implement the alternative. The financial analysis is summarized in the executive summary of the Phase A report, **Attachment A**.

Consultant Recommendation:

Love & Associates, Inc. recommended a combination alternate for both Fourmile Canyon Creek and Wonderland creeks. For each creek, the recommended alternate consisted of a combination of the 100-Year Channel, High Hazard Containment, Floodproofing and Status Quo alternatives. The recommendation was developed utilizing a reach-by reach approach.

The Love & Associates' recommendation also made the point that it is important to realize the Fourmile Canyon Creek and Wonderland Creek floodplains are hydraulically connected. Due to topography and the limited channel capacity of Fourmile Canyon Creek, spills from Fourmile Canyon Creek flow into the Wonderland Creek floodplain. Decisions made on floodplain management and mitigation within the Fourmile Canyon Creek floodplain have a direct impact on the Wonderland Creek floodplain. All development within the existing floodplain should be in accordance with the city, county and federal permitting requirements. The UDFCD developed a draft selected plan that endorses the Love & Associates recommendations and provides additional direction to be considered. The UDFCD Selection Plan is presented as **Attachment F**.

Intangible Benefits (Greenways Objectives):

There are numerous intangible benefits that would arise from the implementation of flood mitigation improvements. Many of these intangible benefits are related to other Greenways Program objectives. The intangible benefits that may be realized through flood mitigation include the following:

- Improved traffic movement during floods
- Improved emergency response
- Improved recreation and alternative transportation
- Improved public health and safety, including life safety due to flash flooding
- Improved environment, water quality and riparian habitat
- Lower flood insurance rates for private property owners
- Increased property values
- Creation of urban open land
- Creation of cultural, educational, and scientific resources

These benefits have not been quantified from a monetary perspective and included in the benefit/cost analysis. As a result, the benefit/cost ratios are lower than what would be realized if dollar values were placed upon the intangible benefits.

Other Considerations:

Bigger floods can and will occur. This statement holds true whether you are talking about a 10-year, 100-year or 500-year flood event. The Fourmile Canyon Creek and Wonderland Creek drainageways have not had a significant flood since the early part of the last century. The public awareness of the significance of the flood situation is low since many of the residents in the floodplain have not seen the results of a disaster in their neighborhood. For this reason, staff recommends continued emphasis on public education and awareness as well as flood preparedness. These activities are funded as part of the city's overall flood management program.

Staff Modifications that differ from the Consultant Recommendations:

Attachments G and H are maps that integrate the consultant and staff recommendations for flood mitigation along Fourmile Canyon and Wonderland creeks respectively. Staff modifications are generally consistent with both the consultant recommendations and the UDFCD selected plan, with three modifications.

As part of the public process, a number of additional ideas and flood mitigation alternatives were evaluated. Based on these ideas and evaluations, staff is recommending the following three changes to the recommendations provided in the Phase A Report:

1. Wonderland Creek – Reach 6

On Reach 6 of Wonderland Creek, three structures were determined to be in the HHZ (HHZ) at Poplar Avenue, east of 19th Street, and recommended for city purchase. Additional evaluation has indicated there is a more cost effective and desirable way to mitigate the HHZ on this reach. This alternative eliminates the need to purchase the properties and helps mitigate flooding near the Centennial Middle School. This alternate has a cost of \$933,500 versus the anticipated cost of \$1,593,200 for the alternative that requires the acquisition of existing residences. Staff is recommending this new option instead of the consultant's recommendation.

2. Fourmile Canyon Creek – Reach 6a

On Reach 6a of Fourmile Canyon Creek west of Broadway, there is currently significant commercial/industrial property within the HHZ. Although the commercial/industrial property does not pose the same level of life safety risk as residential property within the HHZ, there is still a basis for concern. Also, the HHZ designation would preclude extensive re-development in this area as called for in the North Boulder Subcommunity Plan. Staff asked the consultant to develop an additional alternate in order to contain the HHZ and floodway, allowing for redevelopment in this area. In the new recommended strategy, the channel would be excavated to contain the overbank flooding and the Yarmouth and Rosewood road crossings would be improved. The cost for this option would be \$2,350,000. Because there are numerous flood mitigation project competing for limited funds, implementation of this alternate would be contingent on redevelopment proposals that provide for significant private financing of the flood mitigation improvements.

3. Fourmile Canyon Creek – Reach 4

On Reach 4 of Fourmile Canyon Creek, comments were received indicating that some property owners would be willing to accept some risk and tolerate mild flooding along Fourmile Canyon

Creek. In particular, the residents of Githens Acres have voiced their concern on the impact of flood mitigation work to the riparian corridor vegetation and associated wildlife habitat. The consultant has recommended 100-year channel improvements in this area based in part on the fact that the estimated benefit cost ratio is greater than 1.

Staff recommends the combined Floodproofing/High Hazard Containment alternate for Fourmile Canyon Creek - Reach 4. Although the benefit/cost ratio for this alternate is somewhat less, the public expense is dramatically reduced. This is the least invasive flood mitigation strategy that still addresses life-safety concerns. In addition, excavation work required by this alternate will allow the city to minimize impacts to riparian corridor vegetation and associated wildlife habitat. This alternate is also intended to secure a continuous maintainable drainageway corridor through Fourmile Canyon Creek - Reach 4.

The following tables summarize the type of improvement recommended for each reach of the creek, with the three modifications in bold as recommended by city staff:

Wonderland Creek		
Reach	Staff Recommendation	Consultant Recommendation
1 - Valmont to Goose Creek	Maintain Existing	Maintain Existing
2 - Foothills Pkwy to Valmont	Floodproofing	Floodproofing
3 - SH 119 to Foothills Pkwy	HHZ Containment & Floodproofing	HHZ Containment & Floodproofing
4 - 28th St. to SH 119	100-Year Channel	100-Year Channel
5 - 26th St. to 28th St.	100-Year Channel	100-Year Channel
6 - 19th St. to 26th St.	HHZ Containment & Floodproofing without acquisition of existing residences	HHZ Containment & Floodproofing with property acquisition
7 - Broadway to 19th St.	Maintain Existing	Maintain Existing
8 - Wonderland Lake to Broadway	Maintain Existing	Maintain Existing

Fourmile Canyon Creek		
Reach	Staff Recommendation	Consultant Recommendation
1a - SH 119 to Boulder Creek	HHZ Containment & Floodproofing	HHZ Containment & Floodproofing
1b - Savannah to SH 119	Maintain Existing	Maintain Existing
2a - 30th St. to Savannah	Maintain Existing	Maintain Existing
2b - 28th St. to 30th St.	100-Year Channel	100-Year Channel
3 - 26th St. to 28th St.	HHZ Containment & Floodproofing	HHZ Containment & Floodproofing
4 - 19th St. to 26th St.	HHZ Containment & Floodproofing	100-Year Channel
5 - Broadway to 19th St.	HHZ Containment & Floodproofing	HHZ Containment & Floodproofing
6a - 7th St. to Broadway	HHZ Containment & Floodproofing	Floodproofing
6b - 4th St. to 7th St.	HHZ Containment & Floodproofing	HHZ Containment & Floodproofing
6c - Foothills to 4th St.	Maintain Existing	Maintain Existing

NEXT STEPS:

Following the consideration and acceptance of the Fourmile Canyon Creek and Wonderland Creek mitigation plan by council, staff will formally present the plans to UDFCD.

Representatives from the UDFCD have seen the staff recommendations and are supportive of the changes. After the adoption by UDFCD, the next phase includes preliminary design and a Community and Environmental Assessment Process (CEAP).

MATRIX OF OPTIONS:

1. Accept the Fourmile Canyon and Wonderland Creek Flood Mitigation Plan, as modified by staff (staff recommendation).
2. Accept the Fourmile Canyon and Wonderland Creek Flood Mitigation Plan, with additional changes and conditions.
3. Reject the Fourmile Canyon and Wonderland Creek Flood Mitigation Plan, and provide direction to staff.

Approved By:

Jane S. Brautigam,
City Manager

ATTACHMENTS:

Attachment A – Phase A Report Executive Summary
Attachment B – Chronology
Attachment C – Study Area Map
Attachment D – WRAB Motion and Utilities Division Staff Comments
Attachment E – Legal Opinion
Attachment F – UDFCD Selected Plan
Attachment G – Fourmile Canyon Creek Flood Delineation
Attachment H – Wonderland Creek Flood Delineation

**FOURMILE CANYON CREEK AND
WONDERLAND CREEK
MAJOR DRAINAGEWAY PLANNING
PHASE A REPORT
ALTERNATIVES ANALYSIS**

EXECUTIVE SUMMARY

The development, evaluation, and recommendation of floodplain alternatives to mitigate existing flooding in both the Fourmile Canyon Creek and Wonderland Creek floodplains within the City of Boulder (City) and Boulder County are presented in this report. This effort is jointly sponsored by the Urban Drainage and Flood Control District (UDFCD) and the City of Boulder, Colorado.

Purpose and Objectives

The purpose of the study is to analyze the existing and future drainage conditions within both the Fourmile Canyon and Wonderland Creek floodplains, develop alternate drainageway planning concepts to mitigate existing flood damages taking into consideration the impacts of the spill flows from Fourmile Canyon Creek to Wonderland Creek, and prepare a preliminary design of an alternative selected by the Project Sponsors. The study is divided into two phases. The first phase (Phase A) of which this report is a part covers the hydrologic, hydraulic, and alternate evaluation aspects of the project. The second phase (Phase B) will cover the preliminary design of the selected alternate(s).

Planning Process

The initial planning effort began in June of 1999 and both a Phase A and Phase B study were completed for Fourmile Canyon Creek. Following the review and input from the Independent Review Panel (IRP) comprised of floodplain experts in 2000, it was recommended that in order to develop a more complete solution for flooding on Fourmile Canyon Creek, a combined Phase A Alternate Analysis report should be undertaken as a combined study of both Fourmile Canyon and Wonderland Creeks. This combined Alternate Analysis began in the Fall of 2006. Since that time, a series of progress meetings have taken place to exchange information and discuss ideas and findings of the combined study. The progress meetings were regularly attended by representatives of the sponsoring agencies. Concurrent with the progress meetings, a series of public meetings were conducted to discuss the planning effort and solicit public input.

The Project Sponsors will review the Phase A report and make a decision on the alternative that is to be studied in greater detail in Phase B of this planning effort. In Phase B, the consultant will prepare a preliminary design of the alternative(s) selected by the Project Sponsors for both streams. The type, size, location of various improvements will be developed in greater detail. In the process, cost estimates will be refined and the relative priorities and phasing of these facilities will be identified. A final Phase B report will be published following selection of the preferred alternative. The Phase B report will serve as a planning tool for the Project Sponsors and private development within the Fourmile Canyon Creek and Wonderland Creek floodplains.

Background Information

The study area includes the Fourmile Canyon Creek floodplain from the mouth of the canyon to its confluence with Boulder Creek and the Wonderland Creek floodplain from downstream of Wonderland Lake to its confluence with Goose Creek. The Fourmile Canyon Creek spill floodplain, which is located between the Fourmile Canyon Creek and Wonderland Creek floodplains from upstream of Broadway to approximately 19th Street, is included in the study area.

Major drainageway planning documents were previously developed for Fourmile Canyon Creek and Wonderland Creek by Greenhorne & O'Mara, Inc in 1984 and 1987 and for Wonderland Creek by Boyle Engineering in 2002. Due to recent development that has occurred in the floodplain and inaccuracies in the original studies, the City of Boulder commissioned a re-study of the Fourmile Canyon Creek floodplain in 1997 and the Wonderland Creek floodplain in 2005. Love & Associates was retained by the City to prepare a Letter of Map Revision (LOMR) submittal to FEMA for these two streams and the LOMR was approved by various City Boards and the City Council in early 2006. The LOMR was submitted to FEMA in March, 2006 and approved by FEMA in November, 2006. The new floodplains became regulatory following the appeal period in late March, 2007.

The LOMR submittal for these two creeks indicated significant problems with the original FEMA regulatory studies, resulting in additional properties being located within the two floodplains. Of particular importance, the re-study identified reaches of Fourmile Canyon Creek west of 19th Street, where, once the channel capacity is exceeded, flood flows overtop the south bank of the creek and flow in a southeasterly direction towards Wonderland Creek. These “spill flows” result in a reduction of flows in Fourmile Canyon Creek downstream of 19th Street but also result in an increase in the flows in Wonderland Creek. During the 100-year flood event, approximately 3,300 cubic feet per second (cfs) is in Fourmile Canyon Creek near the mouth of the Canyon, of this amount approximately 1,600 cfs will overtop the south bank spill and flow toward Wonderland Creek. The remaining 1,700 cfs will remain in the Fourmile Canyon Creek Channel. Likewise, the 100-year discharge in Wonderland Creek significantly increases downstream of the spill inflow. Some of the spill flows return to Fourmile Canyon Creek near 19th Street but the majority of the spill remains in the Wonderland Creek floodplain.

Damage Analysis

All property, structures and infrastructure within the 500-year floodplain were included in the damage analysis which was undertaken as a part of this master planning effort. The damage analysis was calculated using the UDFCD Methodology for Evaluation of Feasibility: Multi-Jurisdictional Urban Drainage and Flood Control Projects. Flood damages were calculated for the 2-, 5-, 10-, 50-, 100-, and 500-year flood events. For the economic analysis, a 50-year project life was chosen, which corresponds to a typical structure life. A 6% annual interest rate was selected, which corresponds to the cost of borrowed capital for the entities involved and a 3% annual rate of inflation was assumed. The net discount rate used in present value calculations was 3%.

Identification of Potential Flood Mitigation Alternates

Early in the study, a broad range of alternates were identified. These alternates were screened following an analysis of each stream and detailed discussions held during progress meetings on a reach by reach basis for each stream. A wide array of options were looked at as potentials for mitigation of the flooding ranging from a ‘do-nothing’ status quo alternate to construction of a 100-year flood channel for each stream confining the spill from Fourmile in its own channel.

Alternates Analysis

A number of alternates were reviewed as a part of this study. The damage analysis and alternate costs for the previous Fourmile Canyon Creek (2000) and Lower Fourmile Canyon Creek (2002) reports were updated and benefits and costs for two additional alternates were developed. The two additional alternates considered for both streams included a High Hazard Containment and Floodproofing of Structures in the spill area between Fourmile Canyon and Wonderland Creeks alternate. Original alternates considered in the initial *Fourmile Canyon Creek Major Drainageway Master Plan* also included both a 50- year and 100-year channel alternate.

The 100-year channel would be designed by an inter-disciplinary team of engineers, geomorphologists and biologists to emulate a natural channel. This alternate would eliminate spills from Fourmile Canyon Creek to Wonderland Creek during the 100-year or smaller flood event. The channel would be designed to UDFCD and City criteria with FEMA and City required freeboard. The 50-year alternate for Fourmile Canyon (only) would contain the 100-year flows but would have no freeboard built into the design. The Urban Drainage and Flood Control District, based on legal opinion from its counsel, has indicated reluctance to participate in any Alternate which includes containment or reduction of the spill unless downstream property owners’ concerns are properly addressed as this would negatively affect downstream properties on Fourmile Canyon Creek.

The High Hazard Zone is defined as those areas where the product number of velocity (measured in feet per second) times flow depth (measured in feet) equals or exceeds four, or where flow depths equal or exceed four feet. These portions of the 100-year floodplain pose an unacceptably high hazard to human safety. In the high hazard zone, the construction, expansion or enlargement of any structure intended for human occupancy or establishment of a new parking lot is prohibited. The High Hazard Containment alternate would remove structures identified in either stream from the City’s High Hazard Flood Zone through direct purchase of the property, the enlargement of road crossing structures, channel excavation, and/or floodproofing or a combination thereof. This alternate does not eliminate the out of channel bank floodplain; however, it reduces flood levels to those structures in the High Hazard Zone for increased safety when evacuating occupied buildings and allows for emergency access to residential structures.

Floodproofing is a combination of adjustments and/or additions of physical features installed in, on or around individual structures designed to eliminate or reduce the potential for flood damage to the structure. Floodproofing consists of the techniques and approaches for preventing or minimizing flood damages to a structure and its contents in flood hazard areas. Floodproofing techniques range from: the construction of levees and flood walls around a structure, to installing water-tight doors and windows, physically raising the structures elevation using fill or pilings, measures designed to reduce water seepage

and/or resist lateral pressure from flood water in the structure, etc. Floodproofing measures may be applied to new structures as well as retrofitting existing structures which may allow for development within the floodplain in low hazard areas. The purpose of floodproofing is to minimize flood damages by either keeping floodwaters away from damageable property or making the property less susceptible to damages when floodwaters reach the structure. Floodproofing does not eliminate all flood damages but can, if done correctly, significantly reduce damages from flooding. The City may offer guidance and disseminate information regarding various floodproofing techniques; however, it would be the responsibility of the individual property owner to implement this alternate for their own individual properties.

Alternates proposed are compared to the Status Quo or Maintain Existing Conditions alternate. Maintain existing floodplain configuration would adopt the new floodplain mapping without proposing mitigation improvements at this time. Additional non-structural methods including flash flood forecasting and warning systems and evacuation plans would also be recommended for implementation. Flood insurance and floodproofing of structures would also be recommended (at the individual property owner’s expense). Floodplain regulations would be strictly enforced. Post flood relief would be provided. This alternate requires no new funding, but may sacrifice opportunities to greatly improve Fourmile Canyon Creek and mitigate flooding in the future. A “Do Nothing” solution would offer no opportunity to mitigate spills and flooding to the south of Fourmile Canyon Creek and would offer no opportunity to eliminate flooding to the Waldorf or Crestview Elementary Schools.

Reach by Reach cost estimates were prepared for the each of the alternates analyzed (five in the Fourmile Canyon Creek floodplain and four in the Wonderland Creek floodplain).

Each of the alternates analyzed for both streams will still incur an expected damage during flood events. Examples of these damages would include isolated bank erosion locations in the constructed “natural” channel alternate or wide spread damage in the maintaining of the existing floodplain configuration alternate.

One method commonly used to compare alternatives is the benefit/cost (B/C) ratio. In general, the higher the B/C ratio the more cost effective is an alternate. In this study, the benefit/cost ratio compares the total cost to implement a flood control alternative with the benefits that would be realized if that flood control alternative were implemented. The total cost to implement a flood control alternative was calculated as the sum of the construction costs, property acquisition costs (land and structure), right-of-way required to implement the alternate and O&M costs. The benefit that would be realized if the flood control alternative is implemented was calculated as the difference between flood damages under existing conditions minus flood damages that would be incurred after implementation of the alternative.

Benefit/Cost Ratio =
$$\frac{[\text{Existing Flood Damages}] - [\text{Future Flood Damages with Alternative in Place}]}{\text{Cost to Implement Alternative}}$$

A B/C ratio greater than one (1) indicates the benefit received is greater than the cost to implement the alternative. A B/C ratio equal to one (1) indicates the benefit received is the same as the cost to implement the alternative. A B/C ratio less than one (1) indicates the benefit received is less than the cost to implement the alternative.

Comparison of benefits and costs must be made for the same time frame. Benefits stemming from reduced flood damages occurring annually over the life of the project cannot be compared directly with construction costs, which generally occur over a short period of time near the beginning of the project. All benefits and costs must be converted to either present value or annual amounts before comparison, using an appropriate discount rate, which accounts for the time value of money. For this study all costs were converted to present value. Present value calculations assumed a 50-year project life, which corresponds to the typical structural life, and a discount rate of 3% (6% annual interest rate minus 3% annual rate of inflation).

The benefit/cost ratio for each alternate for the entire study reach of each creek is as follows:

Fourmile Canyon Creek			
Alternate 1	50-Year Channel B/C =		1.43
Alternate 2	100-Year Channel B/C =		1.34
Alternate 3	Status Quo B/C =		0.00
Alternate 4	Floodproofing B/C =		1.96
Alternate 5	High Hazard Containment B/C =		0.08

Wonderland Creek			
Alternate 1	100-Year Channel B/C =		1.92
Alternate 2	Status Quo B/C =		0.00
Alternate 3	High Hazard Containment B/C =		0.44
Alternate 4	Floodproofing B/C =		3.64

There are numerous intangible benefits that would arise from the implementation of flood mitigation improvements. By definition, intangible benefits are difficult to measure and are not directly quantifiable in terms of dollar value or dollars spent for their usage. The intangible benefits that may be realized through flood mitigation include the following:

- Improved traffic movement during floods.
- Improved emergency response.
- Improved public health and safety.
- Improved environment, water quality and riparian habitat.
- Lower flood insurance.
- Potential for scientific, educational, historical amenities.
- Increased property values.
- Creation of cultural, educational, and scientific resources.

Because intangible benefits are not directly quantifiable in terms of a dollar value they are not included in the benefit/cost analysis. As a result, the benefit/cost ratios are lower than what would be realized if dollar values were placed upon the intangible benefits.

In addition to the benefit/cost ratios presented above, a number of additional evaluation factors should be considered when choosing a course of action to mitigate flood damages within the Fourmile Canyon Creek and Wonderland Creek floodplains. Below is a list of some of the potential evaluation factors:

Evaluation Factors

- Flood Mitigation
 - Life Safety
 - Property damage
- Environment
 - Temporary Disturbance
 - Long-term benefit
 - Groundwater
- Transportation
 - Automotive
 - Bicycle/Pedestrian
- Development/Re-Development
 - Growth Management
 - Affordable Housing
- Aesthetics
- Benefit/Cost Ratio
- Construction Cost
- Recreation
- Permitting Requirements
- Impacts to Fourmile Canyon Creek
- Impacts to Wonderland Creek
- Conformance with other Planning Documents
- Competing Priorities
- Public Acceptance
- Operation and Maintenance

Bigger floods can and will occur. This statement holds true whether you are talking about a 10-year, 100-year or 500-year flood event. The Fourmile Canyon Creek and Wonderland Creek floodplains have not had a significant flood in the recent documented past. The public awareness of the significance of the flood situation is low since many of the residents in the floodplain have not seen the results of a disaster, or had to clean up after a flood in their neighborhood or experienced the injury to or loss of a family member or friend in a flood event.

Recommended Alternate

The contract Love & Associates, Inc. has with the Urban Drainage and Flood Control District requires that the consultant make a recommendation as to the best overall alternate solution, taking into account a variety of information developed throughout the master planning process for both Fourmile Canyon and Wonderland Creeks.

The firm of Love & Associates, Inc. is recommending a combination alternate for both Fourmile Canyon Creek and Wonderland Creek. In developing the Recommended Alternate we evaluated in combination the alternates utilizing a reach-by reach approach.

For each creek the recommended alternate consists of a combination of the 100-Year Channel, High Hazard Containment, Floodproofing and Maintain Status Quo.

In Reaches 5 and 6 of Fourmile Canyon Creek, the 100-Year Channel and 50-Year Channel alternates result in a change in the spatially varied flow distribution in the floodplain which would require channelization to the confluence with Boulder Creek. Love & Associates, Inc. believes that complete channelization of Fourmile Canyon Creek from Reach 5 or 6 to its confluence with Boulder Creek is not a viable option. The Urban Drainage and Flood Control District has indicated they are not willing to participate in a solution which incorporates containment/channelization of all flows from upstream to the confluence with Boulder Creek. Since these alternates change the flow distribution that currently exists in the floodplains of both streams, channelization creates both liability and life safety risks if bigger floods were to occur. Lands could be inundated by the introduction of flood waters where they would not have existed prior to the re-distribution of flood waters by either of these alternates. Love & Associates, Inc. is not recommending either a 50 or 100-year channel alternate upstream of the spill zone for these reasons. In some downstream reaches where the 100-year alternate resulted in a B/C ratio greater than 1, the 100-year alternate is recommended with a reduced conveyance required. In Reaches 2b and 4 on Fourmile Canyon Creek the 100-year channel altlernate is recommended. The 100-year channel downstream of the spill zone contains the reduced flow that remains after the spill from Fourmile Canyon Creek to Wonderland Creek. Likewise, in Reaches 4 and 5 on Wonderland Creek where the 100-year alternate resulted in a B/C ratio greater than 1, Love & Associates is recommending this alternate. For both creeks the 100-year channel is designed to contain the 100-year discharge and provide a minimum of 1’ of freeboard. This freeboard contains the 500-year flow, making floodproofing unnecessary in these reaches. Additionally, in reaches where 100-year improvements are implemented, flood insurance would also no longer be required. It should be noted that unless 100-year improvements are implemented thus eliminating properties from the floodplain, flood insurance is required with all other solutions including a 50-year channel alternate and floodproofing which provides a degree of flood protection but does not remove the property from the floodplain.

The High Hazard Containment Alternate for both creeks has a benefit/cost ratio of less than one (1); however, no credit is given in the analysis for life safety. Since life safety is of primary concern to this consultant, this alternate is the basis of our recommendation. The High Hazard Containment Alternate removes all residences from the high hazard flood zone allowing safe evacuation and emergency access during a 100-year flood event. The floodproofing alternate has a high benefit/cost ratio and the dollars spent by individual property owners constructing improvements to protect their individual properties offer significant protection to structures and contents during flood events. A combination of the High Hazard Containment and Floodproofing Alternate is recommended for Reaches 1a, 3, 5, and 6b on Fourmile Canyon Creek and for Reaches 3, and 6 on Wonderland Creek. Additionally, the Floodproofing Alternate is recommended for Reach 6a on Fourmile Canyon Creek and for Reach 2 on Wonderland Creek. .For individual reaches on both creeks these alternates are recommended in tandem.

The benefit/cost ratio of this combined alternate ranges from 0-2.65 on Fourmile Canyon Creek, and 0-5.34 on Wonderland Creek. With implementation of this combined alternate, flood insurance would still be required by most lenders and individual property owners would be strongly encouraged to purchase flood insurance whether or not a mortgage on their property is in effect.

In Reaches 1b, 2a, and 6c on Fourmile Canyon Creek and for Reaches 1, 7, and 8 on Wonderland Creek, no structures are being impacted. For each alternate analyzed, these reaches required no work. Therefore, the Maintain Existing Alternate is recommended for these reaches.

Tables ES.1 and ES.2 summarize the recommended alternate for each reach as well as the B/C ratio and a breakdown of public and private costs for implementing the alternate. In the tables below, it should be noted that the dollar costs listed under the ‘private’ category are for those costs that would be incurred by individual property owners to floodproof their own properties.

**Table ES.1
Recommended Alternate
Fourmile Canyon Creek**

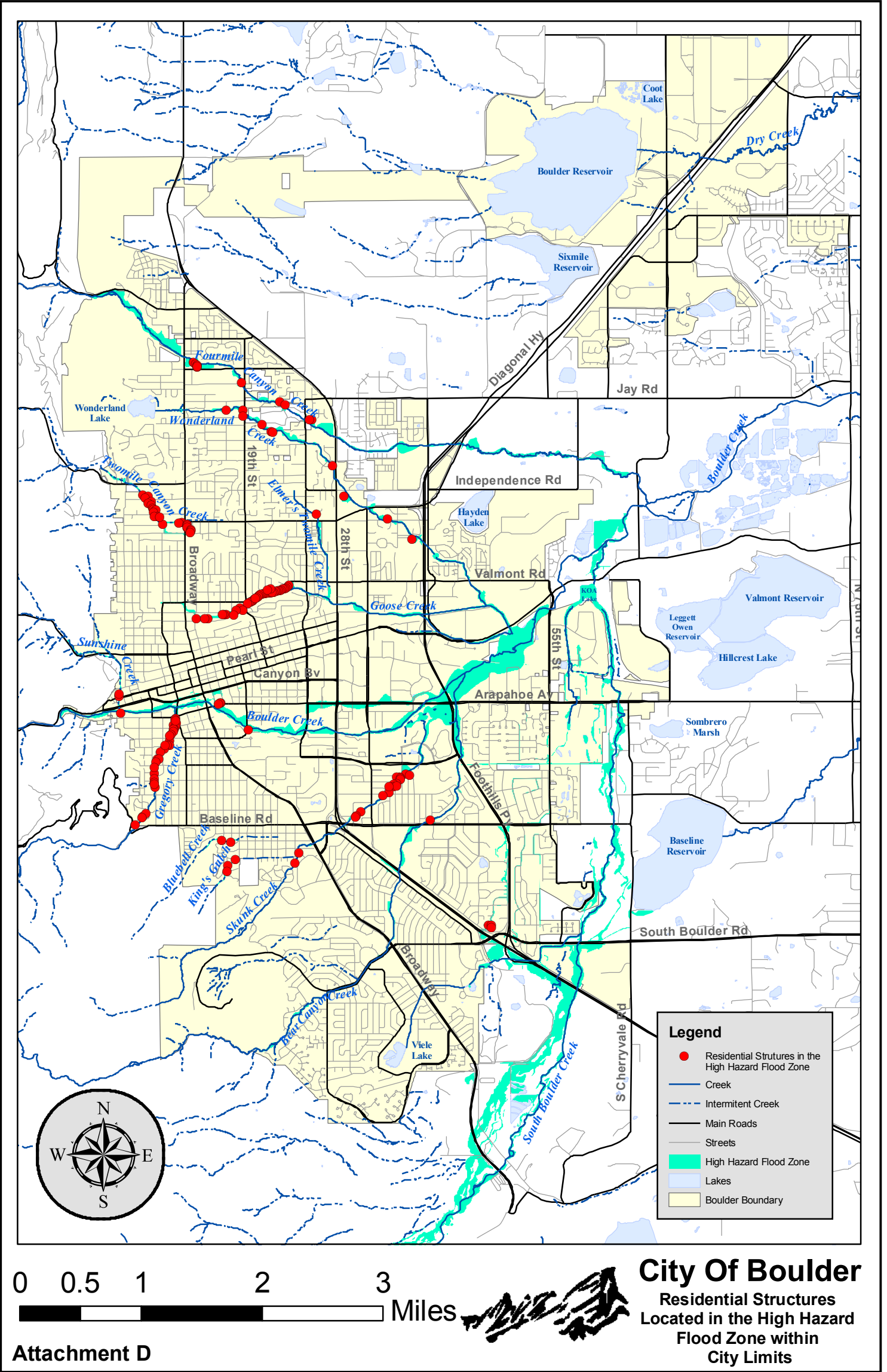
Reach	Alternate	B/C Ratio	Cost		
			Total	Public	Private
Reach 1a	HHZ Containment/Floodproofing	0.08/0.95	\$1,583,800	\$1,025,000	\$558,800
Reach 1b	Maintain Existing	0	\$1,188,000	\$1,188,000	
Reach 2a	Maintain Existing	0	\$442,000	\$442,000	
Reach 2b	100-Year Channel	2.65	\$1,283,660	\$1,283,660	
Reach 3	HHZ Containment/Floodproofing	0.35/1.18	\$900,200	\$741,000	\$159,200
Reach 4	100-Year Channel	1.88	\$6,730,860	\$6,730,860	
Reach 5	HHZ Containment/Floodproofing	0.12/4.42	\$798,400	\$394,000	\$404,400
Reach 6a	Floodproofing	1.68	\$3,130,600	\$290,000	\$2,840,600
Reach 6b	HHZ Containment/Floodproofing	0.03/4.44	\$762,700	\$595,000	\$167,700
Reach 6c	Maintain Existing	0	\$173,000	\$173,000	
Total			\$16,993,220	\$12,862,520	\$4,130,700

Table ES.2
Recommended Alternate
Wonderland Creek

Reach	Alternate	B/C Ratio	Cost		
			Total	Public	Private
Reach 1	Maintain Existing	0	\$618,000	\$618,000	
Reach 2	Floodproofing	0.61	\$539,400	\$332,000	\$207,400
Reach 3	HHZ Containment/Floodproofing	0.39/1.37	\$10,236,600	\$7,307,000	\$2,929,600
Reach 4	100-Year Channel	5.34	\$7,110,300	\$7,110,300	
Reach 5	100-Year Channel	4.75	\$4,057,800	\$4,057,800	
Reach 6	HHZ Containment/Floodproofing	0.51/0.52	\$5,024,300	\$3,168,000	\$1,856,300
Reach 7	Maintain Existing	0	\$807,000	\$807,000	
Reach 8	Maintain Existing	0	\$289,000	\$289,000	
Total			\$28,682,400	\$23,689,100	\$4,993,300

Figures ES-1a-e and ES-2a-c depict the specific alternate being proposed by this consultant for its Recommended Plan for each reach of each stream.

It is important to realize the Fourmile Canyon Creek and Wonderland Creek floodplains are hydraulically connected. Due to topography and the limited channel capacity of Fourmile Canyon Creek, spills from Fourmile Canyon Creek flow into the Wonderland Creek floodplain. Decisions made on floodplain management and mitigation within the Fourmile Canyon Creek floodplain have a direct impact on the Wonderland Creek floodplain. All development within the existing floodplain should be in accordance with the City, County and Federal permitting requirements.



0 0.5 1 2 3 Miles

Attachment E: Critical Facility Information

Protection of critical facilities from the impacts of flooding has become an important element in local floodplain management. Numerous states, counties and local governments have adopted regulations for critical facilities and many more have included recommendations to adopt critical facilities regulations in local Multi-Hazard Mitigation Plans.

In recent years the Federal Emergency Management Agency (FEMA) has outlined guidelines for critical facilities. FEMA states that for some activities and facilities, even a slight chance of flooding poses too great a threat. These activities and facilities should be given special consideration when formulating regulatory alternatives and floodplain management plans.

As such, FEMA defines four kinds of critical facilities:

- Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic, and/or water-reactive materials;
- Hospitals, nursing homes, and housing likely to have occupants who may not be sufficiently mobile to avoid injury or death during a flood;
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for flood response activities before, during, and after a flood; and
- Public and private utility facilities which are vital to maintaining or restoring normal services to flooded areas before, during, and after a flood.

Boulder City Council endorsed the development of protection measures for critical facilities following a January 29, 2002 Study Session on Floodplain Policies. Council later adopted a recommendation to develop 500-year protection standards for critical facilities in the 2004 Comprehensive Flood and Stormwater Master Plan (CFS).

As a result of the CFS recommendation and existing research on critical facilities regulations and guidance from across the nation, a critical facilities ordinance is currently being developed and the following proposed definition and categorization of critical facilities is being developed for Boulder:

“Critical facility,” for floodplain purposes, means a facility, including without limitation, a structure, infrastructure, property, equipment or service, that if flooded may result in severe consequences to public health and safety or interrupt essential services and operations for the community at any time before, during and after a flood. A critical facility is classified by the following categories: (1) Essential Services, (2) Hazardous Materials, (3) At-risk Populations, and (4) Vital to Restoring Normal Services.

Essential services facilities include without limitation public safety, emergency response, emergency medical, designated emergency shelters, communications, public utility plant facilities and equipment, and transportation lifelines.

The sub-categories of essential services facilities can be further defined as:

- *Public safety (police, fire and rescue, emergency management)*
- *Emergency response (emergency responders, vehicle and equipment storage, emergency repair materials, alternative governmental work centers)*
- *Emergency medical (hospitals, urgent care, ambulance services)*
- *Designated emergency shelters*

- *Communications (telephone, cable systems, satellite dish systems, cellular systems, television, radio, news papers, emergency warning systems)*
- *Public utility plant facilities and equipment for treatment, generation, storage, pumping and distribution (water, wastewater, power, gas)*
- *Transportation lifelines (primary access routes, emergency evacuation routes, bridge and culvert crossing structures, airports, rail systems, mass transit, critical roadways)*

Hazardous materials facilities include without limitation facilities that produce, distribute, use, store, deliver in quantity, or sell highly volatile, flammable, explosive, toxic and/or water-reactive materials.

The sub-categories of hazardous material facilities can be further defined as:

- *Chemical and pharmaceutical plants (chemical plant, chemical company, pharmaceutical company)*
- *Laboratories*
- *Refineries and bulk plants(bulk fuel)*
- *Hazardous waste storage and disposal sites*
- *Gasoline and propane sales stations (service station)*

At-risk population facilities include without limitation medical care, congregate care, schools, guest lodging, and places of assembly.

The sub-categories of at-risk population facilities can be further defined as:

- *Medical care (hospitals, clinics, nursing homes)*
- *Congregate care (senior housing, independent living centers, day care, assisted living)*
- *Public and private schools (pre-schools, K-12 schools, colleges and universities, vocational centers, after-school care)*
- *Guest lodging (hotels, motels, bed and breakfast)*
- *Places of assembly (sports arenas, theaters, meeting halls and churches, community centers)*

Vital to restoring normal services facilities include without limitation public utility infrastructure, government operations and major employment centers.

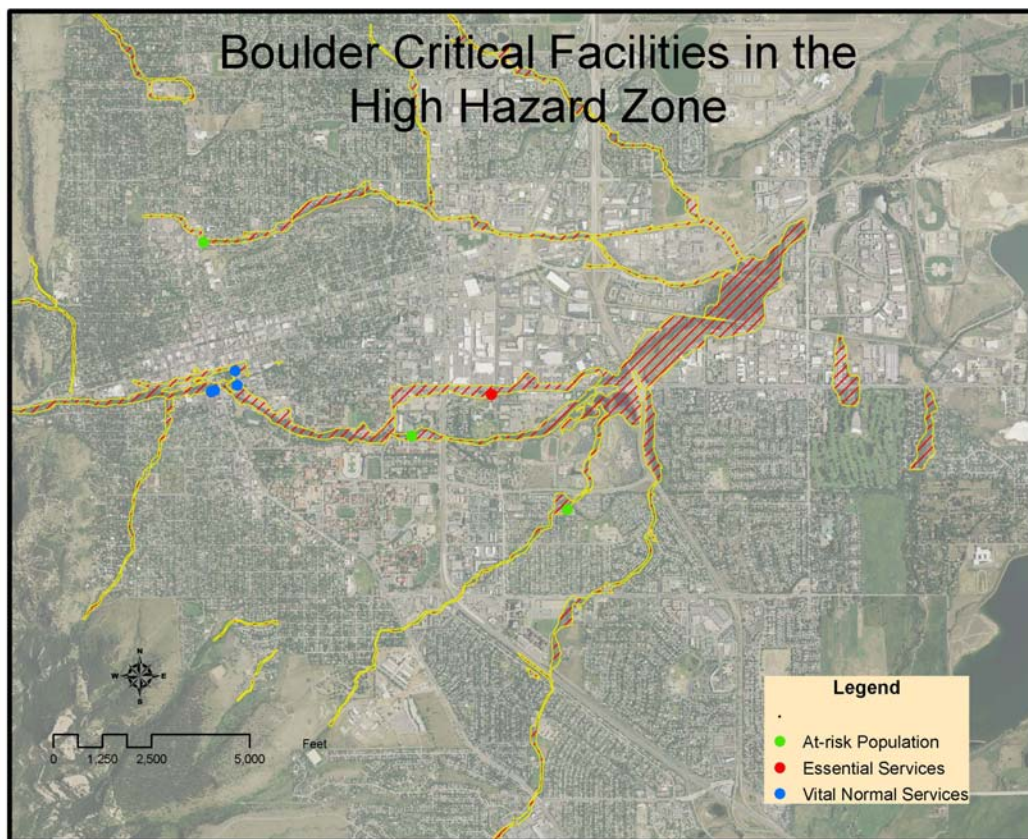
The sub-categories of vital to restoring normal services facilities can be further defined as:

- *Public utility infrastructure (water, wastewater, power, gas)*
- *Government operations (public records and libraries, courts and jails, building permitting and inspection services, community administration and management, maintenance and equipment centers)*
- *Major employment centers (local, state and federal offices, major industries, large corporate offices)*
- *Parcel Services (mail, parcel service, shipping)*

Staff has researched the location and type of all facilities that would currently meet the proposed definition. Existing structures, denoted by critical facility type, which are located in the City's High Hazard Zones, Conveyance Zones, 100 year floodplains, and 500 year floodplains are presented below:

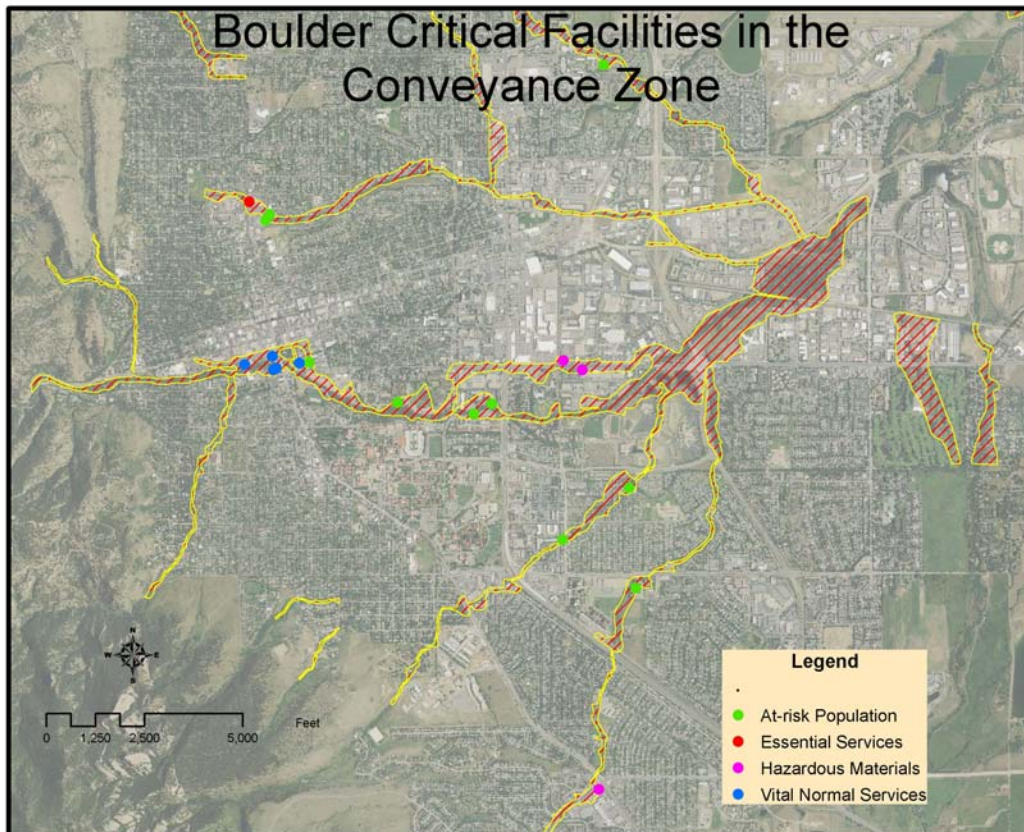
High Hazard Zone Facilities

Number	NAME	ADDRESS	Category	Subcategory	Second Subcategory
1		1301 North Street	At-risk Population	Congregate Care	Day Care
2		1345 28th Street	At-risk Population	Congregate Care	Day Care
3	Crestview Christian Reformed	3545 Madison Ave	At-risk Population	Places of Assembly	Church
4	New Britain Building	1101 Arapahoe Ave	Essential Services	Communications	Warning Systems
5	Boulder Fire Station # 3	30th & Arapahoe	Essential Services	Communications	Warning Systems
6	Boulder Fire Station 3	1585 30th St.	Essential Services	Public Safety	Fire
7	New Britain Building	1101 Arapahoe Ave	Vital Normal Services	Government Operations	Administration and Management
8	Atrium Building	1300 Canyon Blvd	Vital Normal Services	Government Operations	Administration and Management
9	Boulder Building Maintenance	1720 13th St	Vital Normal Services	Government Operations	Maintenance and Equipment
10	Park Central Building	1739 Broadway	Vital Normal Services	Government Operations	Permitting and Inspection



Conveyance Zone Facilities

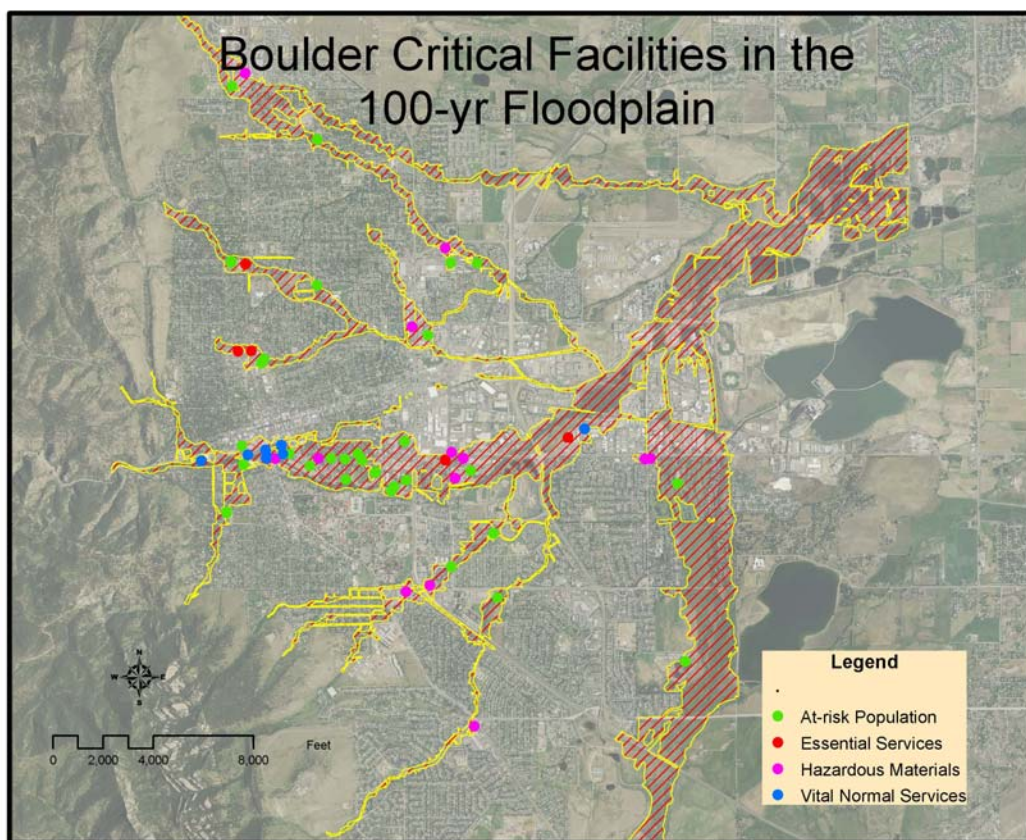
Number	NAME	ADDRESS	Category	Subcategory	Second Subcategory
1		1330 Alpine Ave.	At-risk Population	Congregate Care	Day Care
2		3375 34th St.	At-risk Population	Congregate Care	Senior Housing
3	Millenneum Harvest House	1345 28th St	At-risk Population	Guest Lodging	Hotel
4	Alandi Ashram	1705 14th St	At-risk Population	Places of Assembly	Church
5	Saint Andrew Presbyterian Church	3700 Baseline	At-risk Population	Places of Assembly	Church
6		805 30th Street	At-risk Population	Congregate Care	Day Care
7	CU Married Student Housing	Marine St	At-risk Population	Schools	Student Housing
8	Boulder Medical Center	2750 Broadway	Essential Services	Emergency Medical	Clinic
9	Crossroads AMOCO	3005 Arapahoe Ave	Hazardous Materials	Gasoline and Propane	Service Station
10	Grizzly Gasoline and Store	3200 Arapahoe Ave	Hazardous Materials	Gasoline and Propane	Service Station
11	Conoco	601 S. Broadway	Hazardous Materials	Gasoline and Propane	Service Station
12	Boulder Municipal Building	1777 Broadway	Vital Normal Services	Government Operations	Administration and Management
13	Old Main Public Library	900 Canyon Blvd	Vital Normal Services	Government Operations	Library



100 Year Floodplain Facilities

Number	NAME	ADDRESS	Category	Subcategory	Second Subcategory
1		2202 Arapahoe	At-risk Population	Congregate Care	Day Care
2		2727 29th St	At-risk Population	Congregate Care	Day Care
3		4072 N. 19th	At-risk Population	Congregate Care	Day Care
4		745 College Ave.	At-risk Population	Congregate Care	Day Care
5		2525 Taft Dr.	At-risk Population	Congregate Care	Senior Housing
6	The Atrium: Brookdale Senior Living	3350 30th St.	At-risk Population	Congregate Care	Senior Housing
7	Briar Rose Bed and Breakfast	2151 Arapahoe Ave	At-risk Population	Guest Lodging	Bed and Breakfast
8	Quality Inn	2020 Arapahoe Ave	At-risk Population	Guest Lodging	Hotel
9	Marriott - Boulder	2660 Canyon Blvd	At-risk Population	Guest Lodging	Hotel
10	St Julien Hotel	900 Walnut St	At-risk Population	Guest Lodging	Hotel
11	Bethel United Methodist Church	1925 Glenwood Ave	At-risk Population	Places of Assembly	Church
12	East Boulder Community Center	5660 Sioux Dr	At-risk Population	Places of Assembly	Meeting Hall
13	Spice of Life Event Center	5706 Arapahoe Ave	At-risk Population	Places of Assembly	Meeting Hall
14	West Senior Center	909 Arapahoe Ave	At-risk Population	Places of Assembly	Meeting Hall
15		1001 Hawthorn Ave.	At-risk Population	Schools	After School Care
16		1150 7th Ave.	At-risk Population	Schools	After School Care
17	Living School	1852 Arapahoe Ave	At-risk Population	Schools	Private K-12 Schools
18	Shining Mountain Waldorf School	999 Violet Ave	At-risk Population	Schools	Private K-12 Schools
19	Foothills Elementary School	1001 Hawthorn Ave.	At-risk Population	Schools	Public K-12 Schools
20	Flatirons Elementary School	1150 7th St	At-risk Population	Schools	Public K-12 Schools
21	Boulder High School	1604 Arapahoe	At-risk Population	Schools	Public K-12 Schools
22	University of Colorado	CU-Boulder East Campus	At-risk Population	Schools	Public Universities
23	CU Married Student Housing	Newton Court	At-risk Population	Schools	Student Housing
24	People's Medical Clinic	3303 N. Broadway	Essential Services	Emergency Medical	Clinic
25	Boulder Community Hospital	1100 Balsam	Essential Services	Emergency Medical	Hospital
26	Boulder Foothills Community Hospital	4747 Arapahoe	Essential Services	Emergency Medical	Hospital
27	Boulder Sheriff	1777 6th St.	Essential Services	Public Safety	Police
28	CU Environmental Health	East Campus - 30th and Marine St	Hazardous Materials	Chemical and Pharmaceutical	Pharmaceutical Company
29	Arapahoe and Broadway Conoco	1201 Arapahoe Ave	Hazardous Materials	Gasoline and Propane	Service Station
30	A&A AMOCO	1595 55th St	Hazardous Materials	Gasoline and Propane	Service Station
31	Diamond Shamrock	1704 Arapahoe Ave	Hazardous Materials	Gasoline and Propane	Service Station
32	Boulder Gas	2700 Baseline	Hazardous	Gasoline and	Service Station

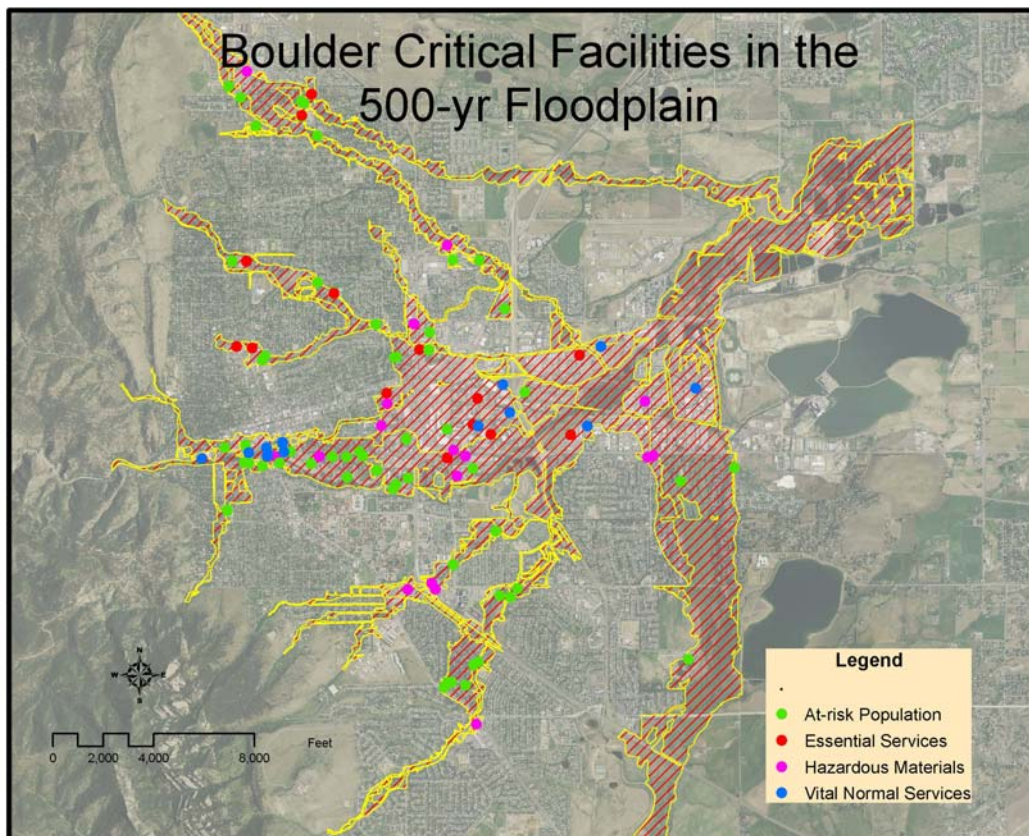
			Materials	Propane	
33	Circle K	2877 Baseline	Hazardous Materials	Gasoline and Propane	Service Station
34	Diagonal AMOCO	2990 Diagonal Hy	Hazardous Materials	Gasoline and Propane	Service Station
35	Boulder Gas	2995 28th St	Hazardous Materials	Gasoline and Propane	Service Station
36	No Broadway Silco Gas	4501 N Broadway	Hazardous Materials	Gasoline and Propane	Service Station
37	Conoco	5500 Arapahoe Ave	Hazardous Materials	Gasoline and Propane	Service Station
38	Boulder County Justice Center (CJC)	1777 6th St.	Vital Normal Services	Government Operations	Courts and Jails
39	Ball Aerospace	1600 Commerce	Vital Normal Services	Major Employment Centers	Major Industries



500 Year Floodplain Facilities

Number	NAME	ADDRESS	Category	Subcategory	Second Subcategory
1	City Assisted Housing on Arapahoe	951-53 Arapahoe Ave	At-risk Population	Congregate Care	Assisted Living
2		1825 Upland Ave	At-risk Population	Congregate Care	Day Care
3		2675 Mapleton	At-risk Population	Congregate Care	Day Care
4		3130 Repplier Dr	At-risk Population	Congregate Care	Day Care
5		3280 Dartmouth	At-risk Population	Congregate Care	Day Care
6		3340 Dartmouth	At-risk Population	Congregate Care	Day Care
7		1286 Sumac Avenue	At-risk Population	Congregate Care	Independent Living
8		2635 Mapleton Ave	At-risk Population	Congregate Care	Independent Living
9		3535 Eastman Avenue	At-risk Population	Congregate Care	Independent Living
10	Boulder Presbyterian Manor	1050 Arapahoe Ave.	At-risk Population	Congregate Care	Senior Housing
11	Canyon Pointe Housing	700 Walnut St	At-risk Population	Congregate care	Senior Housing
12	Boulder University Inn	1632 Broadway	At-risk Population	Guest Lodging	Hotel
13	Residence Inn by Marriott	3030 Center Green Dr	At-risk Population	Guest Lodging	Hotel
14	Courtyard by Marriott	4710 Pearl East Cir	At-risk Population	Guest Lodging	Hotel
15	Congregation Boani Shalom	1527 Cherryvale Rd	At-risk Population	Places of Assembly	Church
16	Boulder Meeting of Friends	1825 Upland Ave	At-risk Population	Places of Assembly	Church
17	Unity Church	2855 Folsom Ave	At-risk Population	Places of Assembly	Church
18	S Broadway Church of the Nazarene	300 S Broadway	At-risk Population	Places of Assembly	Church
19	Boulder Valley Assembly of God	3901 Pinon St	At-risk Population	Places of Assembly	Church
20	Congregation HAR Ha Shem	3950 Baseline Ave	At-risk Population	Places of Assembly	Church
21	Century Boulder Theater	1700 29th St	At-risk Population	Places of Assembly	Theater
22		1897 Sumac Ave	At-risk Population	Schools	After School Care
23		3130 Repplier Dr	At-risk Population	Schools	After School Care
24	Shining Mountain Waldorf School	1179 Union Ave	At-risk Population	Schools	Private K-12 Schools
25	Rocky Mountain School	5490 Spine Rd	At-risk Population	Schools	Private K-12 Schools
26	Crest View Elementary School	1897 Sumac Ave	At-risk Population	Schools	Public K-12 Schools
27	Columbine Elementary School	3130 Repplier Dr	At-risk Population	Schools	Public K-12 Schools
28	KBCO Radio	2500 Pearl St.	Essential Services	Communications	News Papers
29	Crest View Elementary	1897 Sumac Ave	Essential Services	Communications	Warning Systems
30	Columbine School	3130 Repplier Dr	Essential Services	Communications	Warning Systems
31	Pridemark Paramedic Service	3297 Walnut St.	Essential Services	Emergency Medical	Emergency Medical
32	Yards	5050 Pearl St	Essential Services	Emergency Response	Emergency Responders

33	Boulder Fire Station 5	4365 19th St.	Essential Services	Public safety	Fire
34	Public Safety Building	1805 33rd St.	Essential Services	Public Safety	Police
35	RTD	1707 Exposition	Essential Services	Transportation Lifelines	Mass Transit
36	Xcel Boulder Terminal	2500 28th St	Essential Services	Utility Plant	Power
37	Roche	2075 55th St.	Hazardous Materials	Chemical and Pharmaceutical	Pharmaceutical Company
38	Total Petroleum	1884 Folsom Ave	Hazardous Materials	Gasoline and Propane	Service Station
39	Sinclair	2375 Canyon Blvd	Hazardous Materials	Gasoline and Propane	Service Station
40	Parks and Recreation Maintenance	5050 Pearl St	Vital Normal Services	Government Operations	Maintenance
41	Boulder County Clerk and Recorder	1750 33rd St	Vital Normal Services	Government Operations	Public Records
42	Fed Ex	2205 Central Ave	Vital Normal Services	Postal and Shipping	Parcel Service
43	United Parcel (UPS)	3795 Frontier Ave.	Vital Normal Services	Postal and Shipping	Parcel Service
44	US Postal Facility	1860 38th St.	Vital Normal Services	Postal and Shipping	US Post Office
45		3650 Martin Drive	At-risk Population	Congregate Care	Day Care
46	Minders Day Care	3685 Martin Drive	At-risk Population	Congregate Care	Day Care



Staff is developing management strategies for the above critical facilities. These strategies are as follows:

Management Strategy	Use Types
1, 6	Administration and Management
4	After School Care
4	Assisted Living
0	Bed and Breakfast
3	Bulk Fuel
3	Chemical Company
3	Chemical Plant
1	Church
1, 5	Clinic
1	Community Center
1, 6	Courts and Jails
4	Day Care
1, 6	Emergency Medical
1, 6	Emergency Responders
7	Federal Offices
6	Fire
1, 6	Hospital
2	Hotel
4	Independent Living
0	Library
1, 3, 6	Maintenance
1, 3, 6	Maintenance and Equipment
1, 3	Major Industries
0	Mass Transit
1	Meeting Hall
2	Motel
0	News Papers
0	Parcel Service
1, 6	Permitting and Inspection
1,3	Pharmaceutical Company
6	Police
1, 6	Power
4	Pre-schools
4	Private K-12 Schools
4	Public K-12 Schools
1, 6	Public Records
4	Public Universities
0	Radio Station
4	Senior Housing
3	Service Station
1, 6	Sports Arena
0	Student Housing
1, 6	Telephone
1	Theater
0	US Post Office
4	Vocational Centers
6	Warning Systems
1, 3, 6	Wastewater
1, 3, 6	Water

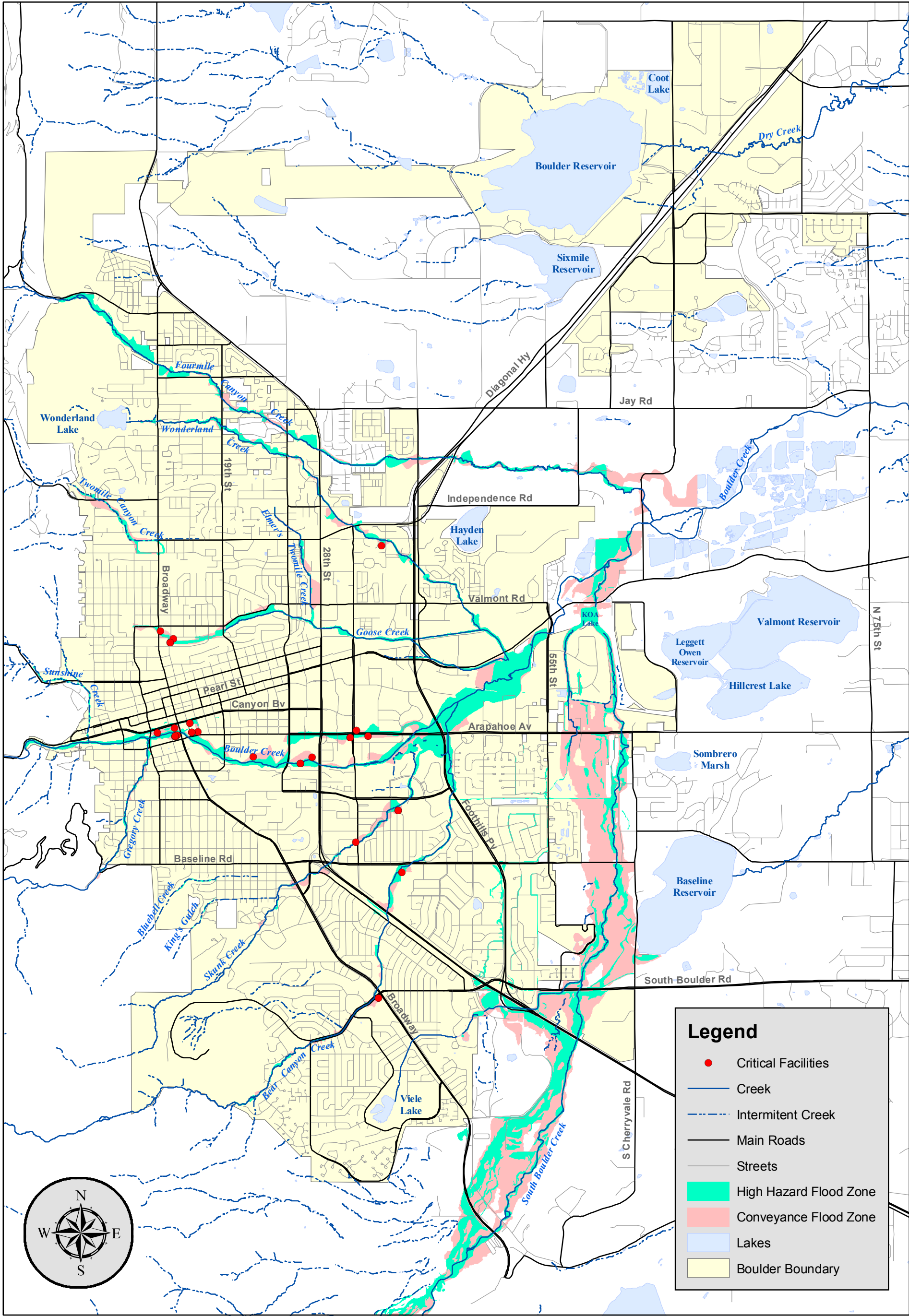
Management Strategies:

- 0 Remove from critical facilities definition.
- 1 Only regulate facilities with an occupancy limit above 50. Upon change of use, new use or use expansion these facilities will need to develop an emergency management plan.
- 2 Upon change of use, new use or use expansion these facilities will need to develop an emergency management plan. These plans will need to be located on the door of each room.
- 3 Regulate facilities that store hazardous chemicals. Upon change of use, new use, or substantial modifications and substantial improvements all hazardous materials must be located above the five hundred-year base flood elevation or be floodproofed to a foot above this elevation. For all other modifications proposed or modified hazardous material must be located above the five hundred-year base flood elevation or be floodproofed to a foot above this elevation.
- 4 Regulate facilities that provide care for 12 or more children/students/residents. Upon change of use, new use or use expansion these facilities will need to develop an emergency management plan.
- 5 For urgent care, emergency care and dialyses clinics regulate to management strategy 6. Remove all other clinics from critical facilities definition
- 6 Upon change of use, new use, or substantial modification/substantial improvement, the critical facility shall be, to the extent possible, located outside the limits of the five hundred-year floodplain. Construction of critical facilities shall be permissible within the five hundred-year floodplain if no feasible alternative site is available. Critical facilities constructed within the five hundred-year floodplain shall be constructed on properly compacted fill and shall have the lowest floor (including basements) elevated two feet above the one hundred-year base flood elevation or one foot about the five hundred-year base flood elevation, whichever is higher. Access routes elevated to no less than 6 inches below the five hundred-year base flood elevation shall be provided to all critical facilities to the extent possible.

For all other improvements the proposed additions must be, to the extent possible, located outside the limits of the five hundred-year floodplain. Construction of additions within the five hundred-year floodplain shall be constructed on properly compacted fill and shall have the lowest floor (including basements) elevated two feet above the one hundred-year base flood elevation or one foot about the five hundred-year base flood elevation, whichever is higher. Access routes elevated to no less than 6 inches below the five hundred-year base flood elevation shall be provided to all critical facilities to the extent possible.
- 7 Federal offices will follow the management strategies of the building's land use.

Emergency management plans will at a minimum include either an evacuation plan (to be developed by a licensed architect or licensed engineer) or a shelter in place plan (to be developed by a licensed structural engineer)

If a facility has more than one use the management strategy of the most restrictive use will apply.



0 0.5 1 2 3 Miles



City Of Boulder
Critical Facilities Located
in the High Hazard &
Conveyance Flood Zones
within City Limits